

WHATEVER
HAPPENED TO
DOLLY
THE SHEEP?



FOCUS

THE LAST GREAT ENIGMA OF OUR SOLAR SYSTEM

WHERE ARE
ALL OUR
ACTIVE
SPACECRAFT?

DOES ZERO-G
AFFECT
ASTRONAUTS'
DREAMS?

WHAT WOULD
MARTIAN
WATER TASTE
LIKE?

What will Juno unearth
beneath Jupiter's surface?

HOW WILL
TIM PEAKE
ADAPT TO LIFE
ON EARTH?

HOW CLOSE
CAN WE
GET TO A
BLACK HOLE?

WHY DO
ASTRONAUTS
LOVE **PRAWN**
COCKTAIL?



**WHY ARE
WE GETTING
SO FAT?**

The reason 'eat less, move more'
doesn't always work

PLUS

**How to build
a mile-high
skyscraper**

#296 | £4.30 JULY 2016
sciencefocus.com

FEED YOUR MIND





Pearson

Join our Assessment Associate Team

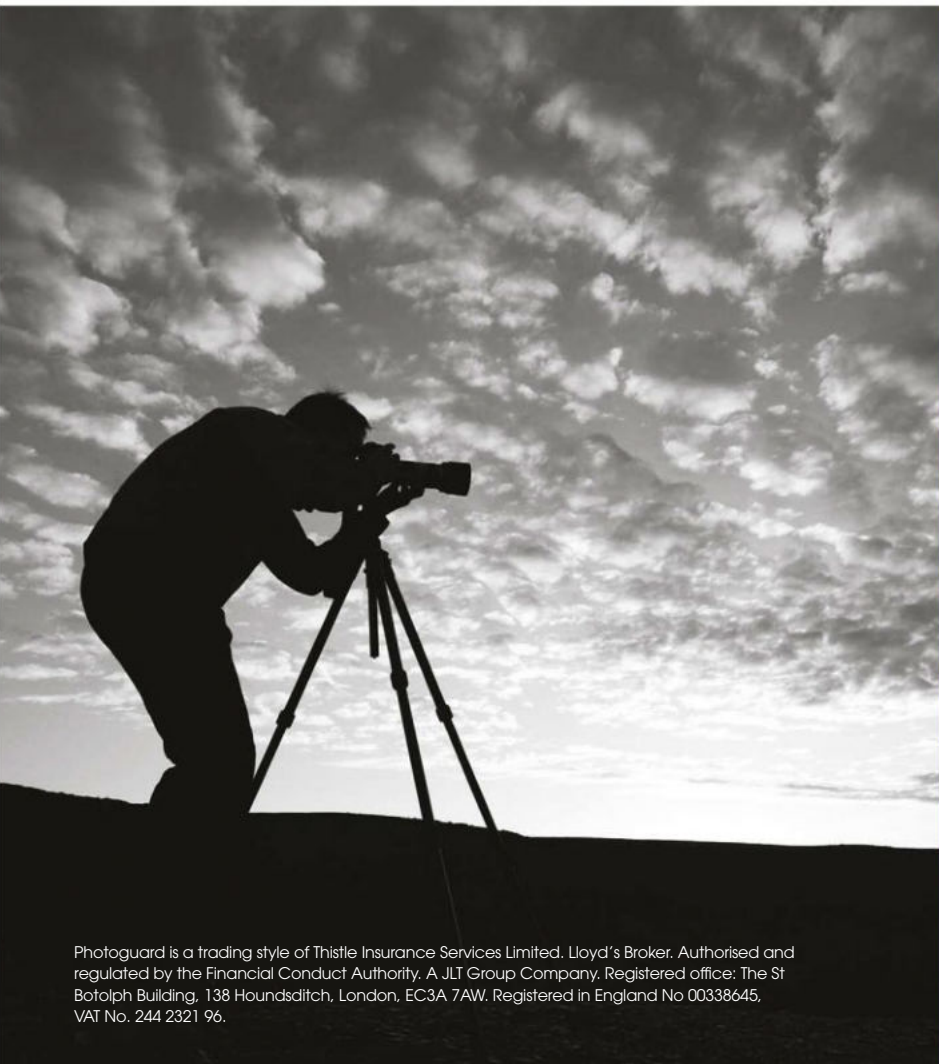
Pearson have exciting opportunities for science teachers to become Standards Verifiers for our BTEC in Applied Science. We are keen to recruit teachers across the UK who are currently teaching or recently retired.

This is an excellent opportunity to:

- Develop your understanding of assessment
- Interact with fellow educational professionals
- Inspire fresh ideas and approaches to teaching your subject
- Boost your income



For more information and how to apply, please visit our website www.edexcel.com/aa-recruitment or email us at aaresourcing@pearson.com



Whilst you frame the perfect shot...

...let us protect your passion.

Photoguard provides insurance for theft, accidental damage, hire costs* and 20 days worldwide cover as standard – keeping you doing what you love.

0333 004 6555

www.photoguard.co.uk

*Following a successful claim

Photoguard is a trading style of Thistle Insurance Services Limited. Lloyd's Broker. Authorised and regulated by the Financial Conduct Authority. A JLT Group Company. Registered office: The St Botolph Building, 138 Houndsditch, London, EC3A 7AW. Registered in England No 00338645, VAT No. 244 2321 96.

Photoguard
insuring the UK's photographers

Recordings

The Flash
Dazzling US superhero
Meet Barry Allen, a CSI investigator
suddenly develops a need for speed.

Most Recent

sky 1

The Flash

sky MOVIES

Cinderella

sky MOVIES

Mad Max Fury Road

sky 1

24

Monday, 7.11pm

sky

MUSIC TO YOUR EARS

**FREE
BLUETOOTH
HEADPHONES***
WORTH £50

WHEN YOU BUY ANY
TOMTOM SPARK
MUSIC EDITION
GPS FITNESS WATCH



TomTom 
SPARK
GPS FITNESS WATCH

AVAILABLE FROM



John Lewis

amazon.co.uk

SELFRIDGES & CO

Sweaty Betty

*TomTom Bluetooth Headphones. Terms and conditions apply.
Visit www.tomtom-promotions.com/freeheadphones. Proof of purchase required. Available in the UK Only, for participants 18 and older. Subject to availability.

WELCOME



Once upon a time, I quite fancied going to space (not that NASA was knocking down the door). The gadgets, the outfits, the scenery... what's not to like? But now I'm having second thoughts. Did you know that astronauts have a constant head cold? Without gravity keeping bodily fluids where they belong, they work their way up into the head, where they tend to stay, leaving astronauts feeling permanently stuffy. They

don't tell you that in school. Nor do they mention that the skin on the soles of the feet tends to moult off after prolonged absence from the floor. And don't get me started on 'wet burps'...

Space, it seems, is a bit of a disgusting place. But if that doesn't put you off, then there are more discoveries to make in our Q&A space special. For instance, on p50 we take inventory of all the active research spacecraft, while on p44 we reveal what the Juno mission might uncover beneath Jupiter's clouds.

Here on Earth, it's been 20 years since scientists cloned Dolly the sheep. On p64, we catch up with Bill Ritchie, one of the scientists who worked on the project, to find out where cloning technology has found a home today. And finally if you, like me, find it hard say no to a slice of cake – or three – then turn to p80 where geneticist Dr Giles Yeo explains how our genes compel us to overeat.

Daniel Bennett

Daniel Bennett, acting editor

IN THIS ISSUE



SHANNON WALKER

What's it really like to go into space? In 2010, scientist and NASA astronaut Shannon spent five months aboard the International Space Station, making her the perfect person to answer our questions. → p56



DR GILES YEO

Over 62 per cent of UK adults are obese or overweight and the figure seems set to rise. Geneticist Giles looks at the research suggesting the issue is more complex than simply 'eating less and moving more'. → p80



DR ELIZABETH PEARSON

Elizabeth is news editor on *Sky At Night Magazine* and will be keenly following the Juno mission in July. This month, she reveals the secrets that the mission could uncover. → p44

IN THIS ISSUE



- 1 THE LAST GREAT ENIGMA OF OUR SOLAR SYSTEM → P44
- 2 Q&A 26-PAGE SPACE SPECIAL → P36
- 3 WHATEVER HAPPENED TO DOLLY THE SHEEP? → P64
- 4 WHY ARE WE GETTING SO FAT? → p80
- 5 HOW TO BUILD A MILE-HIGH SKYSCRAPER → P72

CONTACT US

➔ Advertising

neil.lloyd@immediate.co.uk
0117 300 8276

➔ Letters for publication

reply@sciencefocus.com

➔ Editorial enquiries

editorialenquiries@sciencefocus.com
0117 314 7388

➔ Subscriptions

focus@servicehelpline.co.uk
0844 844 0257*

➔ Other contacts

sciencefocus.com/contact

WANT MORE BBC FOCUS?

FOLLOW SCIENCEFOCUS

f FACEBOOK

t TWITTER

p PINTEREST

y YOUTUBE

CONTENTS



REGULARS

8 Eye opener

10 Reply

13 Discoveries

All of the best news from the world of science this month.

29 Innovations

The tech that's getting us excited.

63 Robin Ince

Can science explain why we love festivals?

79 Robert Matthews

Just because quantum theory is weird, it doesn't mean weirdos should hijack it.

95 Helen Czerski

Making glass from sugar.

102 Out there

This month's best books, TV shows and day trips. PLUS: Visit Tokyo with Tomoko Nakanishi.

109 Next month

Find out what's coming up in the August issue.

114 My life scientific

Hannah Fry chats to Helen Pilcher about maths, Formula 1 and her dog Molly.

26 Subscribe

Get five issues for £5 when you subscribe to BBC Focus today.



FEATURES

Q&A space special

36

This month, we answer all your cosmic conundrums in our 26-page space special.

Where are all the clones?

64

This year marks 20 years since Dolly the sheep captured the nation's hearts. But why aren't we overrun with clones today?

10 weirdest things evolution left in your body

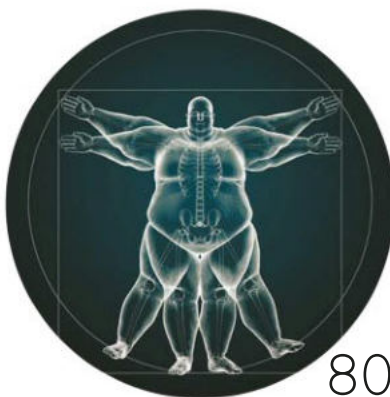
70

Why do we have wisdom teeth? Why do we get goosebumps? It's all down to evolution.

Reaching new heights

72

Frank Lloyd Wright first proposed a mile-high skyscraper 60 years ago. But could we build one today?



80

Are my genes to blame if my jeans don't fit?

80

Over 60 per cent of UK adults are now overweight or obese. But is it because of our lifestyles, or can we blame our podginess on our parents?

Every second counts

88

Our cycling journo pits himself against... erm... himself in a battle to become the most efficient thing on two wheels.


How do we know... how animals perceive the world

96

It's taken scientists a long time to establish how animals' senses work, and they're still making discoveries today.



64



EYE OPENER

Mesmerising meanders

THJÓRSÁ TRIBUTARIES,
SOUTHWEST ICELAND

On the south coast of Iceland, translucent tendrils wend their way through volcanic soils. These channels of water are all heading towards the river Thjórsá – Iceland's longest river.

The tributaries have their source in a nearby lake. As they flow slowly towards the river they rearrange the iron-rich soil, constantly forming new channels and creating these intricate patterns.

The image was captured by Hans Strand from a helicopter at an altitude of around 91m (300ft). Approximately one kilometre to the left of this scene is the North Atlantic Ocean.

"The land in this region has been shaped by the river Thjórsá over thousands of years," says Finnur Pálsson, a researcher at the Institute of Earth Sciences, University of Iceland. "As the glacial river reaches the coast, it slows down and deposits the loose sediments it's carrying. Over time, the sediments pile up to create the landscape that you can see in this photo."

PHOTO: HANS STRAND



REPLY

Your opinions on science, technology and BBC Focus

reply@sciencefocus.com

BBC Focus, Tower House,
Fairfax Street, Bristol, BS1 3BN

@sciencefocus

www.facebook.com/sciencefocus

MESSAGE OF THE MONTH

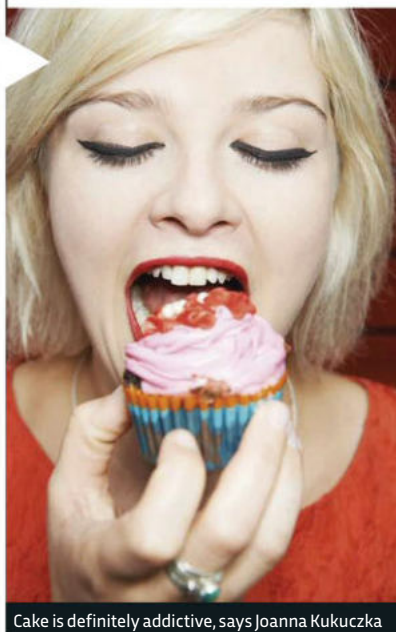
Hard to stomach

In your February issue, Lilian Anekwe writes about food addiction. It felt disturbing to learn that the scientists are still debating whether the addiction exists or not, rather than working on a solution to the problem. The journalist defines the term 'addiction' before embarking on the precipitous journey of explaining where we currently are. She writes that the criteria include developing tolerance, having withdrawal symptoms and becoming dependent.

That's spot on me and chocolate. Or cake. In fact, I stumbled upon this article after consuming four pieces of cake that day. Not something I wanted to do, especially after three months of healthy eating, but there you go. I downed the last piece and felt sick. It had taken three months to trick my mind into thinking that avocado is a treat, and only three days to forget it. Forget that avocado and water filled me up, gave me energy, and made me light and happy. Now all the energy was gone. I felt defeated. Controlling a craving should be easier, shouldn't it? I love tomatoes, but only eat one at a time, and I certainly wouldn't kill for them. Cake, however, is different on so many levels. I can't stop, even though it's destroying me. The guilt and belly fat build up, the energy levels drop. But I still do it. I still crave another piece of sugary death. What is it, if not evidence that cake can be addictive?

Joanna Kukuczka, Northampton

➔ You're certainly not alone. The rate at which the office snacks turn into a pile of crumbs tells me that the *BBC Focus* team has a similar weakness for baked goods. Turn to p80 to discover how our genetics drive us to seek out these energy-rich foods. – **Ed**



Cake is definitely addictive, says Joanna Kukuczka

Body builders

The article 'Can we build a human?' (June, p34) suggests that the brain might be a modular item that can be unplugged and transferred to another body in the same way that a car engine can be transferred to a new car body. Certainly, the Italian neurosurgeon Sergio Canavero believes he can chop off a patient's head and plonk it onto another body.

This view grossly oversimplifies the relationship between the brain

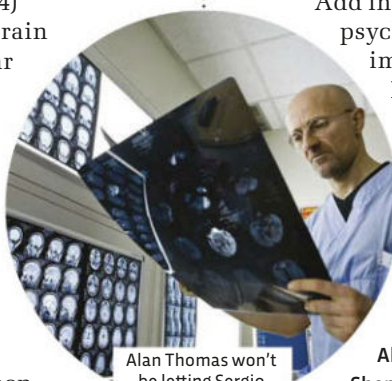
and the body: when I play the guitar, where I place my fingers and how I strike the strings is the result of numerous complex interactions between my brain, nervous system and muscles, in addition to my emotions, which involve such things as hormone levels. All this has built up over years of practice. Give my brain a new body, and that complex chemistry of interactions will have been lost.

Our brains are but one of an orchestra of components, including the levels of hormones in our bodies, sensory signals, muscle movements, the beat of our heart, all of which combine to make us 'us', who we are. Transferring the brain to another body would be to transfer but one – albeit prominent – component of many that work together to make 'us'.

Add in the enormous psychological implications and

I, for one, would not be first in the queue for a body transplant. Thanks, as always, for such thought-provoking articles.

Alan Thomas,
Shepperton



Alan Thomas won't be letting Sergio Canavero anywhere near him

➔ I would certainly be behind you in that queue. That said, the human body and spirit are astoundingly resilient. Who knows what we'll achieve in the future? – **Ed**

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **SteelSeries Siberia 200 gaming headset**, worth £59.99. The stylish headset seamlessly combines great audio and microphone quality with good looks and comfort. steelseries.com



WORTH
£59.99



David Clubb says renewables are vital

Power struggle

Dr Barry Culpin (April, p12) has a poor grasp of energy statistics. In his letter, he claims that the contribution renewables can make to our generating capacity “can only be a small portion of our total needs”. He is obviously unaware that in 2015 renewable energy generated 25 per cent of the UK’s electricity, compared with the 21 per cent contributed by nuclear (statistics from the Department of Energy & Climate Change).

Renewable energy is cost-effective, safe, quickly-deployable and provides employment and revenue for countless individuals and communities across the UK. Nuclear energy scores poorly on almost every comparable metric. **David Clubb, Cardiff**

➔ Dr Barry Culpin is right to highlight the importance of energy storage. It is rapidly dropping in cost, hastening the obsolescence of nuclear energy, and providing a whole host of other positive changes across the entire economy. – **Ed**

A beautiful mind?

I get the impression that Robert Matthews feels that the great minds of our generation are wasting time considering consciousness and its associated mysteries. Perhaps it could be argued that there are more pressing issues to be pondered.

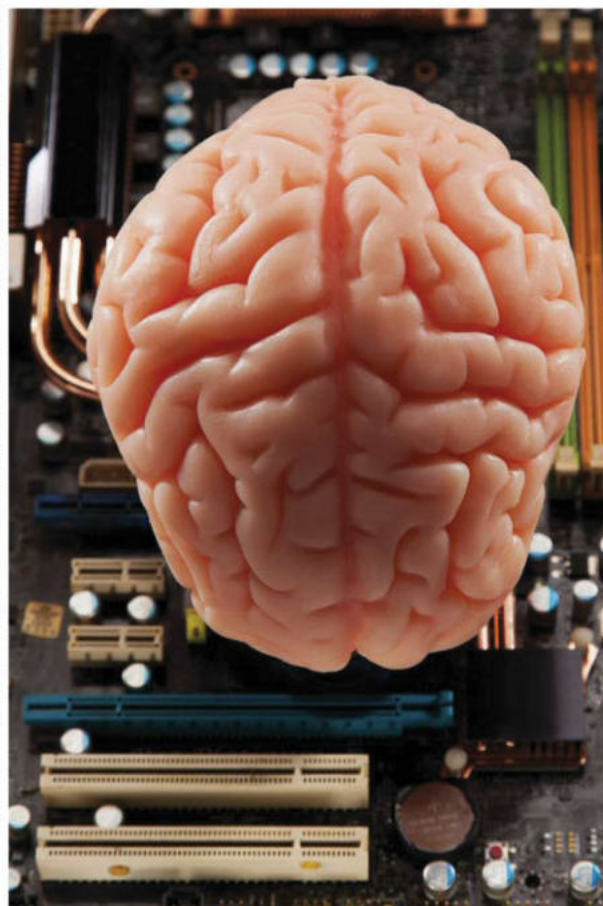
However, in the same issue, it was suggested that there could be a working computer model of a human brain by 2019. If such a thing does happen, then the workings of the brain could potentially be unlocked. We might be able to use the information gathered in advances in neuroscience and apply them to philosophical theories regarding the origins of consciousness. This wouldn’t be possible if there were no such theories.

Arthur Schopenhauer defined a genius as someone whose intellect crushes their will. That such bright minds abandon their work – their means of survival, if this is their employment – to consider bigger issues, is indicative of the fact that they are geniuses and not that they have gone off-course.

Nicola Robertson, via email

Nicola Robertson says that studying consciousness could help us unlock the brain

➔ As I said in the piece, we don’t lack for theories of consciousness. What we need are ways of discriminating between them. – **Prof Robert Matthews**



MORE FOCUS FOR YOU

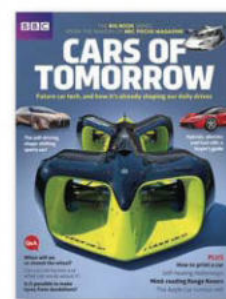
Don’t forget that *BBC Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an award-winning iOS app for the iPad and iPhone, so you can get your fix of science knowledge wherever you go.



Can’t wait until next month to get your fix of science and tech? Brought to you from the team behind *BBC Focus* magazine, the Science Focus website is packed with news, articles and Q&As to keep your brain satisfied. **sciencefocus.com**



Special issue



CARS OF TOMORROW

Supercharge your knowledge of the cars of the future with our latest special edition. It includes a buyer’s guide to different fuel types, expert Q&As, the hottest car-based technology, and more.



Christopher
Ward

C5 Malvern Slimline Square

christopherward.co.uk

DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

JULY 2016

EDITED BY JASON GOODYER

ANTHROPOLOGY

MYSTERIOUS 176,500-YEAR-OLD STONE CIRCLES FOUND

Enigmatic rock structures found deep within a French cave are forcing us to rethink our ideas of Neanderthals

Researcher surrounded by the ancient stone circles within the French caves

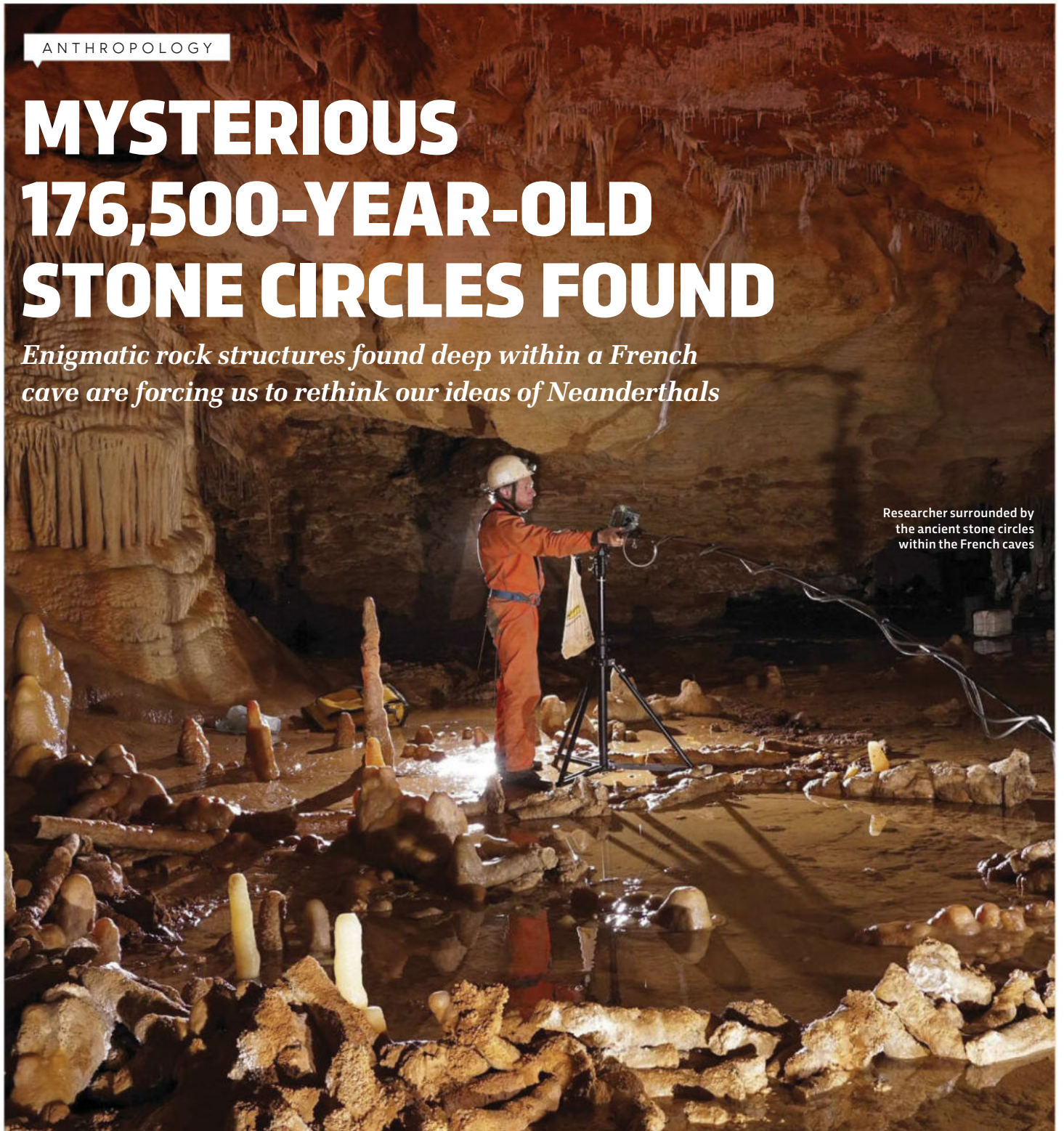


PHOTO: ETIENNE FABRE/SSAC

Neanderthals are often depicted as slow-witted brutes that spent their time clubbing mammoths to death and dragging women around by their hair. But this stereotype is not true.

Archaeologists have discovered complex circular structures made from stalagmites 300 metres inside Bruniquel cave, near Toulouse in southwest France. The limestone structures date back 176,500 years, some 135,000 years before the arrival of modern humans in Europe, indicating that they must have been made by Neanderthals, the only hominins in the area at that time.

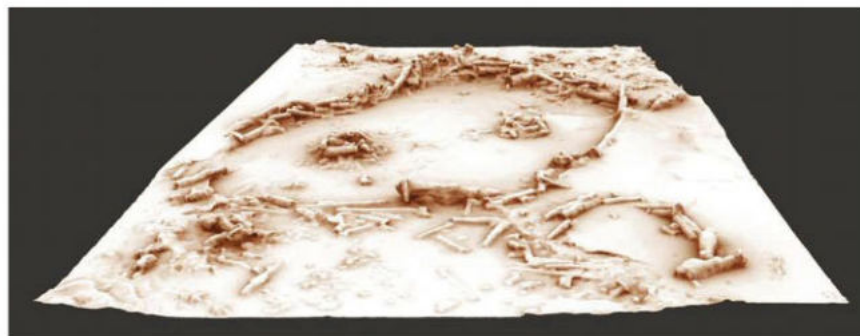
Evidence of scorch marks in the area also suggests that early Neanderthals were able to use fire for warmth and light well before *Homo sapiens* developed the skill.

“The first impression we had of the site was that of a rather old age, certainly Palaeolithic, but perhaps not as old as that,” said project leader Prof Jacques Jaubert, of the University of Bordeaux. “The structures are spectacular and unique. There are virtually no equivalent Neanderthal structures currently known for the same period, and even for more recent periods, for example the Upper Palaeolithic.”

A total of 400 stalagmites weighing around 2.2 tonnes are arranged in rough circles up to four layers deep. Marks left by the Neanderthals wrenching the stalagmites from the cave floor can be seen nearby. It is as yet unclear exactly why the Neanderthals built the circles but the team plans to head back into the cave for further investigations.

“We prefer to wait to return to the site and study it more concretely, for example to excavate or establish test-pits to find some archaeological remains, before determining exactly what it is,” said Jaubert. “All hypotheses are currently just speculation and are not provable.”

“THERE ARE VIRTUALLY NO EQUIVALENT NEANDERTHAL STRUCTURES KNOWN FOR THE SAME PERIOD”



ABOVE: The Vallée de l'Aveyron, near the Bruniquel cave

BELOW: 3D reconstruction of the structures made from stalagmites in the caves

EXPERT COMMENT

Prof Chris Stringer

Research leader in human origins at the Natural History Museum, London

“The purpose of the structures and concentrated combustion zones remain enigmatic, but they demonstrate that some Neanderthals were as much at home deep within the cave as at its entrance.

There are examples of human habitation of this or even greater age 30 or 40 metres into caves in Africa, but the Bruniquel occupation is some 10 times deeper into the cave, and shows constructions as complex as some made by modern humans only 20 or 30,000 years ago.

Accumulations of early human bodies deep within caves are known from Rising Star Cave [near Johannesburg, South Africa] and the Sima de los Huesos [Atapuerca, Spain], but the circumstances and meaning of their deposition are disputed. In Rising Star Cave there is no archaeological material with the skeletons, while at Sima de los Huesos, archaeological material is only loosely associated with the human remains.

The Bruniquel structures are dated to within a long, cold glacial stage, and at that time the cave might have provided a refuge. If there is still-buried debris from occupation, it would help determine whether this was a functional shelter, or something that had more symbolic or ritual significance.

This discovery provides clear evidence that Neanderthals had fully human capabilities in planning and constructing structures, and that some of them penetrated deep into caves where lighting would've been essential. For this reason, the scientists involved should be congratulated.

”

SPACE

Stellar sounds may give keys to the formation of the Milky Way

Astrophysicists from the University of Birmingham have captured the sounds of some of the oldest stars in the Milky Way.

Using a technique known as asteroseismology, the team analysed data recorded by the NASA Kepler/K2 Mission to study resonant oscillations of stars in the Messier 4 globular cluster, a group of 13-billion-year-old stars located 7,200 light-years away in the constellation of Scorpius.

Sound waves trapped inside stars cause them to pulse and wobble, which causes tiny but observable changes in the brightness of the light they emit. Observing these changes allows researchers to determine the frequencies of this internal 'stellar music' and thus the structure of the star. The technique allows astronomers to determine the mass and age of stars more accurately than brightness measurements and opens the door to studying the very early history of our Galaxy.

"We were thrilled to be able to listen to some of the stellar relics of the early Universe," said researcher Dr Andrea Miglio. "The stars we have studied really are living fossils from the time of the formation of our Galaxy, and we now hope to be able to unlock the secrets of how spiral galaxies, like our own, formed and evolved."

By listening to the stars, researchers can figure out how galaxies evolved

IN NUMBERS

390,900

The number of plant species known to science, as estimated by researchers at the Royal Botanic Gardens in Kew.

400 PARTS PER MILLION

The concentration of carbon dioxide in the atmosphere recorded at Cape Grim atmospheric station in Tasmania earlier this month. Many experts believe the figure may never drop lower again.

700 BILLION SOLAR MASSES

The most accurate measurement of the mass of the Milky Way yet, made by researchers at Canada's McMaster University. The figure covers all of the stars, planets, moons, gases and dust, as well as a significant chunk of dark matter. One solar mass is equal to the mass of our Sun.

NATURE

TOP 10 NEW SPECIES OF 2016 NAMED

A red dragon, a 12-million-year-old ape and a carnivorous plant first spotted in a Facebook photo are among the 10 most awesome animals and plants chosen by scientists from more than 18,000 species discovered over the last 12 months.

The list was assembled by the SUNY College of Environmental Science and Forestry (ESF) to mark the birthday of Carl Linnaeus, an 18th-Century Swedish botanist considered to be the father of modern taxonomy. It is believed that 10 million species still await discovery, five times the number that are already known. But species are going extinct faster than they can be identified, putting researchers in a race against time. "We can only win this race to explore biodiversity if we pick up the pace," said ESF president Quentin Wheeler. "In so doing we gather irreplaceable evidence of our origins, discover clues to more efficient and sustainable ways to meet human needs, and arm ourselves with fundamental knowledge essential for wide-scale conservation success."

1 Red dragon

Phyllopteryx dewysea, Western Australia

Considering it is bright red and nearly 24cm long, it's surprising this bizarre fish has escaped our attention for so long. It is only the third species of seadragon to be discovered.

2 Flowering in plain sight

Siravidia solannona, Gabon

Spotted just metres from a main road in Gabon's Monts de Cristal National Park, this flowering tree was confirmed as a new species by molecular analysis. Its closest known relative is a plant found in Tanzania some 3,000km away.

3 Ancient ape

Pliobates cataloniae, Spain

Nicknamed Laia by her discoverers, this ape could be found scurrying up and down the trees of eastern Spain about 11.6 million years ago. The remains date back to a time before the family tree containing humans and great apes diverged from that of gibbons and could teach us more about our evolution.

3D scan of the ruby seadragon

2



3



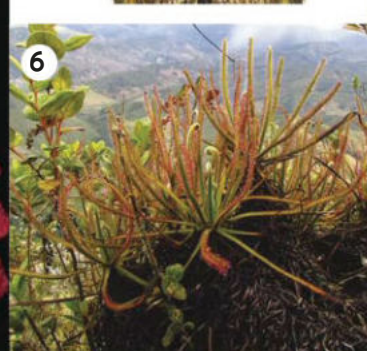
4



5

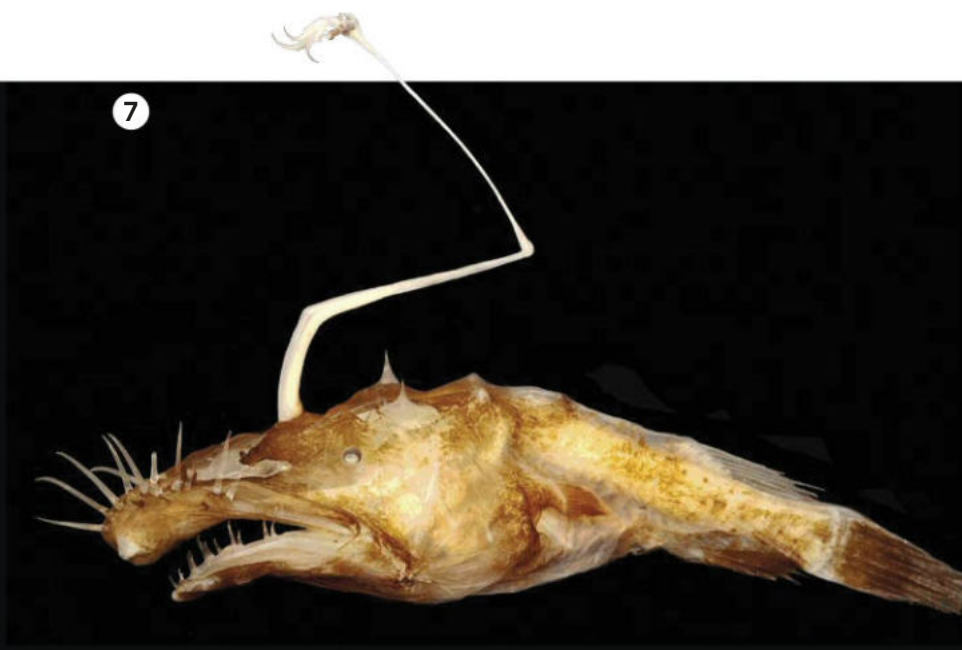


6



1

PHOTOS: JOSEFIN STILLER/NERIDA WILSON/GREG ROUSE, J. HAWKS/WITS UNIVERSITY, THEODORE W. PIETSCH, SOUZA/FERREIRA/SENNA, WASHINGTON TAPIA, PAULO M. GONELLA, MICHAEL DARBY, MARTA PALMERO, THOMAS COUVREUR, JENS KIPPING



4 Bug that builds

Luiuniscus luiuensis, Brazil

Despite being blind, these tiny cave-dwelling isopods build impressive spherical shelters out of mud to protect themselves from predators when moulting, a behaviour never before seen in this family of crustaceans.

5 Please look after this beetle

Phytotelmatrichis osopaddington, Peru

These tiny beetles are around the size of a pinhead and make their homes in the minute pools of water that form in the hollows of plants. They were named after the famous marmalade-loving bear in the hope that it will draw attention to the plight of the Andean spectacled bear that inspired him.

6 Social climber

Drosera magnifica, Brazil

It seems social media does have a use beyond smug status updates about Michelin-starred dinners: this insect-eating plant is thought to be the first new species discovered through photos posted on Facebook. It grows to 120cm in height and is only known to exist on the peak of a single mountain, 1,550m above sea level.

7 Playing the angles

Lasiognathus dinema, Gulf of Mexico

Discovered during the damage assessment programme launched in the wake of the Deepwater Horizon oil spill, this angler fish certainly didn't make it into the top 10 because of its looks. Its oddest feature is its fishing pole-like dorsal fin. In some angler fish, the esca – an organ at the end of its 'pole' – is home to bioluminescent bacteria that produce light to attract prey.

8 Ancestor unearthed

Homo naledi, South Africa

Though yet to be accurately dated, the bones of 15 individual hominins found in the Rising Star cave near Johannesburg are thought to belong to a new species of human ancestor. Dubbed *Homo naledi*, the creature had similar hands and feet to modern humans but has other characteristics more closely resembling earlier hominins.

9 A giant discovery

Chelonoidis donfaustoi, Galapagos

Once thought to be a genetic variant of the tortoise *Chelonoidis porteri*, a closer look at the features of this giant tortoise revealed it to be a new and distinct species. With as few as 250 individuals remaining, it may have been found just in time.

10 Psychedelic sparklewing

Umma gumma, Gabon

This bejewelled beastie is just one of 60 new species of damselfly and dragonfly discovered in Africa in the last year. It takes its Latin name from the 1969 double album by psychedelic rockers Pink Floyd.





SPACE

INFLATABLE SPARE ROOM ADDED TO THE ISS

Talk about expanding your horizons. NASA has successfully installed an inflatable extra room onto the International Space Station.

Dubbed BEAM (Bigelow Expandable Activity Module), the aluminium and fabric unit was deployed following a previous failed attempt. It will remain attached to the ISS for two years to undergo a series of tests to see how well it can protect astronauts from solar radiation, space debris and the extreme temperatures seen in space.

If successful, the technology could help the space agency to colonise Mars. Before sending the first astronauts to the Red Planet, rockets filled with cargo and supplies could be deployed to await the crews' arrival. As they are smaller and lighter than conventional metal habitats, the use of expandable modules could reduce the number of launches



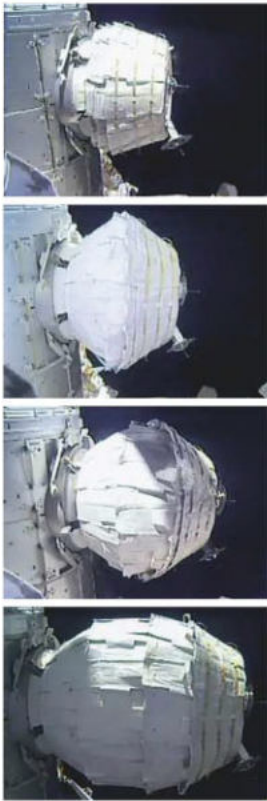
The BEAM is easy to transport and assemble – just don't wear stilettos inside

VITAL STATS

	Mass (kg)	Length (m)	Diameter (m)	Volume (m³)
Packed	1,400	2.16	2.36	3.6
Expanded	1,400	4.01	3.23	16

needed and overall mission costs.

“The International Space Station is a uniquely suited test bed to demonstrate innovative exploration technologies like the BEAM,” said NASA’s William Gerstenmaier. “As we venture deeper into space on the path to Mars, habitats that allow for long-duration stays in space will be a critical capability. Using the station’s resources, we’ll learn how humans can work effectively with this technology in space, as we continue to advance our understanding in all aspects for long-duration spaceflight aboard the orbiting laboratory.”



PHOTOS: BIGELOW AEROSPACE



ANIMALS

Bumblebees' hairs quiver when exposed to static electricity from flowers

BEES SENSE FLOWERS' ELECTRIC SIGNALS WITH THEIR HAIR

With their bold yellow and black markings and fuzzy bodies, bumblebees are some of the most charismatic insects seen in the British summertime. Now, a team from the University of Bristol has found that they use their distinctive fuzz to detect electric signals from flowers.

The researchers found that bumblebees' fuzzy hairs quiver rapidly when exposed to the static electricity created by flowers. By investigating the insects' nervous system they were then able to confirm that they used the hairs to guide them to sources of pollen. The findings suggest that electroreception in insects may be widespread, they say.

"We were excited to discover that bees' tiny hairs dance in response to electric fields, like when humans

hold a balloon to their hair," said research lead Dr Gregory Sutton. "A lot of insects have similar body hairs, which leads to the possibility that many members of the insect world may be equally sensitive to small electric fields."

Electroreception may arise from the bees' hairs being stiff and lightweight, giving them properties similar to the spider hairs and mosquito antennae that are sensitive to sound, the researchers say. Electroreception is common in aquatic mammals, such as sharks, but has been little studied in insects.

Scientists hope that research into how flower signals are perceived, received and acted upon by bees will lead to a deeper understanding of the complex relationship between insects and pollinators that keeps the planet green.



IDENTICAL TWINS

It's better together, at least for twins anyway. A study at the University of Washington has found identical twins have an increased chance of living into their 60s. The effect could be due to the siblings' strong social bond, the researchers say.

PANDAS

Hao Hao, a giant panda at Pairi Daiza Zoo in Belgium, has given birth to a male cub, making her one of only a handful to do so in captivity. There are thought to be fewer than 2,000 pandas left on the Earth, with 300 being homed by zoos.

GOOD MONTH

BAD MONTH

REGIONAL ACCENTS

Jimmy Nail's Geordie brogue could soon be a thing of the past. A Cambridge study of 30,000 Britons across 4,000 locations has found more of us are speaking like southerners. Social mobility and media are to blame, they say.

LAWYERS

Canadian start-up ROSS has built an AI that can search through the entire body of case law in seconds. Type in a query and the barrister bot spits out a stream of legal citations and precedents.



ORIGIN OF LIFE

"The RNA World hypothesis gives us a better insight into how life originated here and elsewhere"

German scientists have made building blocks of RNA through reactions similar to those that may have occurred on early Earth. So did an 'RNA World' exist before life began? We asked biochemist Prof Niles Lehman

What is the RNA World hypothesis?

It's a collection of ideas that suggest that RNA [a nucleic acid related to DNA that is involved in the synthesis of proteins], or something a lot like it, was the first molecule that led to life as we know it here on the Earth. RNA is cool because it has both a genotype and a phenotype: it has a genotype in that it can store and transmit genetic information [now the function of DNA] and it has a phenotype in that it can catalyse a chemical reaction [as proteins do today]. So when that was first realised back in the 1980s, people came up with this idea that if we had

to start with something, a good bet is RNA.

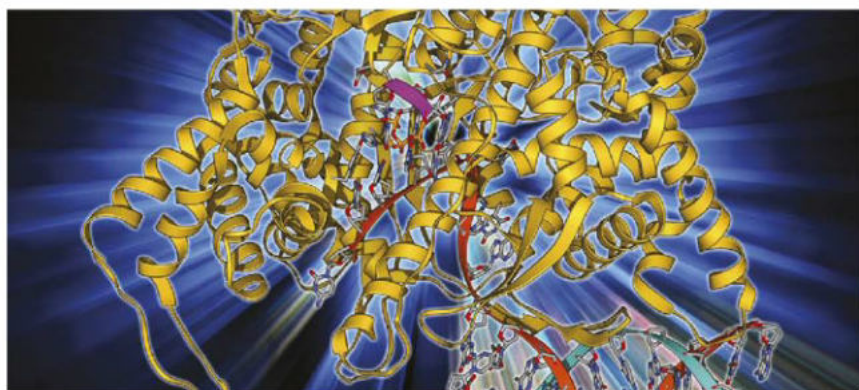
How do we know life came from RNA?

We don't. We'll never know unless we get into a time machine and go back four billion years and see what happened on the Earth. Part of the goal of origins of life research is not to reconstruct the *actual* history of what happened on the Earth, but to reconstruct a *plausible* history. The RNA World hypothesis falls into that realm of a plausible sequence of events that could have led to life. There are a lot of 'molecular fossils' in contemporary biochemistry that suggest RNA was very ancient in the history of life. The fact that ATP is the primary energy currency in cells, and ATP is a piece of RNA, means that many scientists have suggested that RNA had a very rudimentary role in the genesis of life.

How might RNA have been created?

One of the long-standing questions is how do you make the building blocks of RNA on the prebiotic Earth [Earth before life existed]? It's been a challenging synthesis from a chemical point of view. There have been some really nice advances in the last 10 years or so, adding to our repertoire

BELOW: RNA could have played an important role in kick-starting life on Earth





ABOVE: Scientists are keen to establish how life began on early Earth

BELOW: Prof Niles Lehman at Portland State University uses biochemistry to investigate the origins of life



ILLUSTRATION: RAJA LOCKEY

of possible reaction pathways that led from small molecules that would have been available four billion years ago, to the building blocks, or nucleotides, of RNA [represented by the letters A, C, G and U]. The four letters of the building blocks can be split into two types: purines and pyrimidines. U and C are purines, while G and A are pyrimidines. In 2009, Manchester University's John Sutherland showed you could go from some prebiotically plausible molecules to an activated version of the C nucleotide, cytosine. Sutherland's team also showed you could go from prebiotically plausible molecules to at least the nucleotide versions of G and A, guanine and adenine.

Why is it important to study the RNA World?

I think everybody wants to understand their own origins, and one of the biggest unsolved problems in understanding where we came from is how life arose from non-life. It informs our own origins and it also informs the probability that life exists elsewhere in the Universe. Studying the RNA World hypothesis gives us a better insight into how life originated here and elsewhere. It doesn't mean it happened that way, but in the absence of a time machine, it gives us a window into plausibility.

THEY DID WHAT?!

Trees observed 'sleeping'

What did they do?

Researchers from the Vienna University of Technology used precise laser scanners to map the movement of silver birch trees from sunset and sunrise in search for signs of circadian rhythm.

Why did they do that?

Most living organisms, including plants, are known to adapt their behaviour according to the repeating cycles of day and night. Flowers, for example, continue to open and close in rhythm with daily cycles even when they've been locked in a darkened cellar. But this is the first study to be carried out on trees in their natural environment.

What did they find?

While they didn't exactly lie down and curl up for the night, the trees' leaves and branches were shown to droop gradually after sunset, reaching their lowest point a couple of hours before sunrise. In the morning, the branches returned to their original position within a few hours. The effect is thought to be down to changes in internal pressure due to photosynthesis.





"Am I hungry, or not?
Better consult with two
of my neurons"

NEUROSCIENCE

SNAILS MAKE DECISIONS USING JUST TWO BRAIN CELLS

Snails may not be renowned for their brainpower, but researchers at the University of Sussex have found that the molluscs can make complex decisions using just two of their neurons. The discovery could lead to the creation of more efficient robot brains, they say.

By monitoring the brain activity of freshwater snails while they searched for food, the team discovered that key elements of the molluscs' behaviour was controlled by a single pair of neurons. The first lets the snail's brain know food is nearby, and the second tells the brain whether the snail is hungry or not.

"What goes on in our brains when we make complex behavioural decisions and carry them out

"JUST TWO
NEURONS CAN
CREATE
A MECHANISM
THAT DRIVES
AND OPTIMISES
TASKS"

is poorly understood," said study leader Prof George Kemenes. "Our study reveals for the first time how just two neurons can create a mechanism in an animal's brain which drives and optimises complex decision-making tasks."

The system also enables the snails to save energy by reducing brain activity when food is scarce or they aren't hungry.

"Our findings can help scientists to identify other core neuronal systems which underlie similar decision making processes," said Kemenes. "This will eventually help us design the 'brains' of robots based on the principle of using the fewest possible components necessary to perform complex tasks."

PHOTOS: SCIENCE PHOTO LIBRARY, ISTOCK

MEDICINE

STEM CELL INJECTIONS COULD HELP STROKE PATIENTS TO WALK AGAIN

Wheelchair users disabled by stroke are now walking again, thanks to the injection of stem cells directly into their brains.

Surgeons at the Stanford University School of Medicine drilled access holes into 18 stroke patients' heads and injected stem cells derived from donor bone marrow and modified to restore neurologic function. The patients began showing significant improvements in mobility within one month and continued to improve for one year.

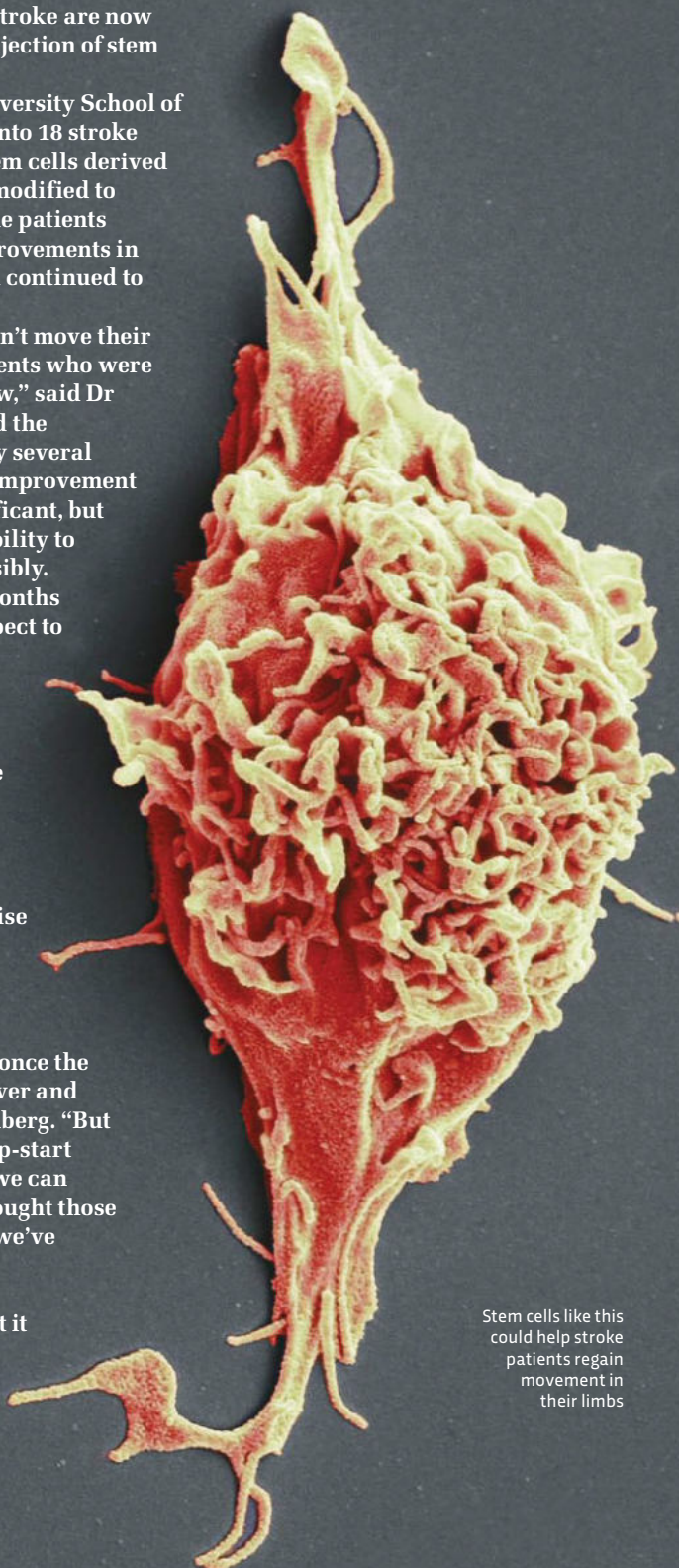
"This wasn't just, 'they couldn't move their thumb, and now they can'. Patients who were in wheelchairs are walking now," said Dr Gary Steinberg, who performed the procedures. "They improved by several standard measures, and their improvement was not only statistically significant, but clinically meaningful. Their ability to move around has recovered visibly. That's unprecedented. At six months out from a stroke, you don't expect to see any further recovery."

Current approved therapies for stroke are only effective if applied within a few hours. This means they are unsuitable for use on most patients due to the time it takes to reach a treatment centre, leaving most survivors with disabilities.

"This study could revolutionise our concept of what happens after not only stroke, but traumatic brain injury and even neurodegenerative disorders. The notion was that once the brain is injured, it doesn't recover and you're stuck with it," said Steinberg. "But if we can figure out how to jump-start these damaged brain circuits, we can change the whole effect. We thought those brain circuits were dead. And we've learned that they're not."

But despite the procedure's promise, Steinberg warned that it is still early days.

"This was just a single trial, and a small one. It was designed primarily to test the procedure's safety," he said.



Stem cells like this could help stroke patients regain movement in their limbs

THE DOWNLOAD

Volatile organic compounds (VOCs)

What are they? Angry vegan activists, perhaps?

Now, you're just being silly. They are a group of chemicals that researchers at Northumbria University have found are responsible for making socks stink.

Er, isn't that just sweat?

Nope. Sweat is odourless until it comes into contact with bacteria on the skin, which it then reacts with to form VOCs.

So how did they find them?

The team had a group of volunteers wear fresh socks for 10 hours and gave another group fresh t-shirts to wear for an intense game of five-a-side football. They then took samples from the socks and t-shirts to determine what chemicals were making them whiff.

So what do they smell like?

Butyric acid smells of rancid butter, dimethyl disulfide of onions, 2-heptanone of bananas, 2-nonanone of flowers and fat, and 2-octanone of apples. Someone pass the air freshener.



VOCs can only be killed at high temperatures

PSYCHOLOGY

HALLUCINOGENS COULD HELP TO TREAT SEVERE DEPRESSION

The psychedelic 'trips' triggered by taking psilocybin, the hallucinogenic chemical in magic mushrooms, could help to treat depression, a small feasibility trial carried out at Imperial College London suggests.

The team used psilocybin to induce powerful psychedelic trips lasting for up to six hours in 12 carefully selected participants with a long history of depression. One week after the treatment all of them were found to be free from depression, with five remaining depression-free for three months. The effect is thought to be due to the action of the drug on receptors in the brain that are sensitive to serotonin, a hormone involved in mood-regulation.

"This is the first time that psilocybin has been investigated as a potential treatment for major depression," explained lead researcher Dr Robin Carhart-Harris. "Treatment-resistant depression is common, disabling and extremely difficult to treat. New treatments are urgently needed, and our study shows

that psilocybin is a promising area of future research."

All of the 12 volunteers had previously failed to respond to courses of conventional antidepressants, with 11 of them also seeing no benefits from psychotherapy. None of them suffered from any serious side effects. The authors warn that it is too early to form strong conclusions about the therapeutic benefits of psilocybin but say the findings show promise.

"The results are encouraging and we now need larger trials to understand whether the effects we saw in this study translate into long-term benefits, and to study how psilocybin compares to other current treatments," said Carhart-Harris.

In the UK, magic mushrooms are a Class A drug. The maximum penalty for supply is life imprisonment.

The active ingredient in magic mushrooms, psilocybin, was given to volunteers in the study



WHAT WE LEARNED THIS MONTH

SUSPENSE IS IN THE AIR IN CINEMAS

The air in cinemas changes according to what's being shown, research by the Max Planck Institute suggests. Comedy, action and suspense produce characteristic chemical signatures in the air because of altered breathing patterns of the viewers.

PARACETAMOL CAN MAKE YOU LESS CARING

It may be the first thing you reach for to get rid of a headache, but popping paracetamol can make you less sensitive to the emotional pain of others, a team at Ohio State University has found.

GROWTH SPURTS MAKE SOME TEENAGE BOYS CLUMSY

Teens who gain more than 3cm in three months tend to be more physically awkward, a team at the University of Bologna has found. The effect is thought to be due to the brain having to adjust to the body's new proportions.

MOLES MAY TOPPLE STONEHENGE IF TEMPERATURES CONTINUE TO RISE

Warmer, wetter weather will create ideal breeding conditions for worms, leading to an abundance of food for burrowing mammals, a study commissioned by UNESCO has found. This may lead to a rise in moles that could destabilise the stones.

PHOTOS: GETTY, ESA

SPACE

Ingredients for life found on Rosetta's comet

Are we all descended from aliens? Life on Earth may have originated in space, new findings from ESA's Rosetta mission suggest.

Traces of glycine, an amino acid commonly found in proteins, and phosphorus, a key component of DNA, have been discovered in the dust surrounding the comet 67P/Churyumov-Gerasimenko.

The finding was made by ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis), a detector designed to 'sniff' the gases surrounding 67P, and confirms the long-theorised possibility that the building blocks for life may have been brought to Earth on a comet.

"The multitude of organic molecules already identified by Rosetta, now joined by the exciting confirmation of fundamental ingredients like glycine and phosphorous, confirms our idea that comets have the potential to deliver key molecules for prebiotic chemistry," said Matt Taylor, ESA's Rosetta project scientist. "Demonstrating that comets are reservoirs of primitive material in the Solar System and vessels that could have transported these vital ingredients to Earth, is one of the key goals of the Rosetta mission, and we are delighted with this result."

The Rosetta probe reached 67P in August 2014 following a 10-year, 6.4 billion kilometre journey through space. ROSINA's first detection of the substances was made in October 2014 with a second being taken in March 2015.

"There is still a lot of uncertainty regarding the chemistry on early Earth and there is of course a

huge evolutionary gap to fill between the delivery of these ingredients via cometary impacts and life taking hold," said co-researcher Hervé Cottin. "But the important point is that comets have not really changed in 4.5 billion years: they grant us direct access to some of the ingredients that likely ended up in the prebiotic soup that eventually resulted in the origin of life on Earth."

BELOW: By investigating the gases surrounding comet 67P, Rosetta has found molecules that may help explain how life on Earth began



SUBSCRIPTION ORDER FORM

Please complete the order form and send to: **FREEPOST IMMEDIATE MEDIA**
(please write in capitals)

UK DIRECT DEBIT

☐ Yes, I would like to subscribe to/renew *BBC Focus* and receive 5 issues for £5. After this my subscription will continue at £17.99 every 6 issues – **SAVING 30%** (please complete form below)

YOUR DETAILS (ESSENTIAL)

Title _____ Forename _____
Surname _____
Address _____
_____ Postcode _____
Home phone no _____
Mobile tel no _____
Email _____

☐ I wish to purchase a gift subscription (please supply gift recipient's name and address on a separate sheet)

Instructions to your bank or building society to pay by Direct Debit



To: the Manager (bank/building society)
Address _____
Postcode _____
Name(s) of account holder(s) _____
Bank/building society account number _____ Branch sort code _____
Reference number (internal use only) _____
Originator's identification number _____
7 1 0 6 4 4
Signature _____ Date ____/____/____

Please pay Immediate Media Co Bristol Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Immediate Media Co Bristol Ltd and, if so, details will be passed electronically to my bank/building society.

Banks and building societies may not accept Direct Debit mandates from some types of account

Your personal information will be used as set out in our privacy policy, which can be viewed online at immediate.co.uk/privacy-policy. Immediate Media Company Limited would love to send you newsletters, together with special offers, and other promotions. Please tick here if you'd prefer not to receive these by email ☐ text message ☐ regular post ☐ telephone ☐
Branded BBC titles are licensed from or published jointly with BBC Worldwide (the commercial arm of the BBC). Please tick here ☐ if you'd like to receive regular newsletters, special offers and promotions from BBC Worldwide by email. Your information will be handled in accordance with the BBC Worldwide privacy policy which can be viewed online at bbcworldwide.com/privacy.aspx

OTHER PAYMENT METHODS

☐ **UK cheque/credit/debit card** – £41.90 for 13 issues, **saving 25%**
☐ **Europe** inc Eire – £58.50 for 13 issues
☐ **Rest of world** – £63 for 13 issues
☐ I enclose a cheque made payable to Immediate Media Co Ltd for £ _____

Visa ☐ Mastercard ☐ Maestro ☐

Issue no ____ Valid from ____ Expiry date ____
Signature _____ Date _____

If credit card address is different, please use the order hotline 0844 844 9747

OVERSEAS Please complete the order form and send to:
BBC Focus, PO Box 279, Sittingbourne, Kent, ME9 8DF

* Offer ends 22 July 2016. Offer only available to UK residents paying by Direct Debit. Your subscription will start with the next available issue. After your first 5 issues, your subscription will continue at £17.99 every 6 issues, saving 30% on the shop price. If you cancel within two weeks of receiving your fourth issue, you will pay no more than £5.

You may photocopy this form

5 ISSUES WHEN YOU SUBSCRIBE



SPECIAL SUBSCRIPTION OFFER:

- Trial your first **5 issues for just £5***
- After your trial period, continue to **save a fantastic 30%** on the shop price, **paying just £17.99 every 6 issues** by Direct Debit
- Receive every issue delivered direct to your door with **FREE UK delivery**
- **Hurry!** Offer ends 22 July 2016

TRY A
SUBSCRIPTION
TO **BRITAIN'S
BEST-SELLING
SCIENCE
MONTHLY**

ES FOR £5*

**SPECIAL
TRIAL OFFER**

SUBSCRIBE TO *BBC FOCUS* TODAY



**NORMALLY
£21.25
YOU PAY
£5***

BBC FOCUS

THE ULTIMATE MAGAZINE FOR CURIOUS MINDS

SUBSCRIBE TODAY



ONLINE

www.buysubscriptions.com/focus

PLEASE QUOTE FOP296



BY PHONE

0844 844 0257⁺

PLEASE QUOTE FOP296



BY POST

FREEPOST
IMMEDIATE MEDIA
(please write in capitals)

+ Calls to this number will cost 7p per minute plus your telephone company's access charge. Lines open weekdays 8am–8pm and Saturdays 9am–1pm
If calling from overseas, please call +44 1795 414 699.

◦ CHORD ◦

YOUR MUSIC. JUST BETTER.



+



+



=



MOJO IS A SMALL DEVICE (DAC) THAT YOU ATTACH TO YOUR PHONE, PC, MAC, OR GAMES CONSOLE FOR EXCEPTIONAL AUDIO PERFORMANCE WHILST ON THE GO, GAMING, PRODUCING, OR JUST LISTENING TO MUSIC. EXPERIENCE STUDIO QUALITY SOUND WHEREVER YOU ARE.



MADE IN THE UK

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

JULY 2016

EDITED BY RUSSELL DEEKS

ROBOTEERS, STAND BY!

*Giant robot battles are
on the horizon*

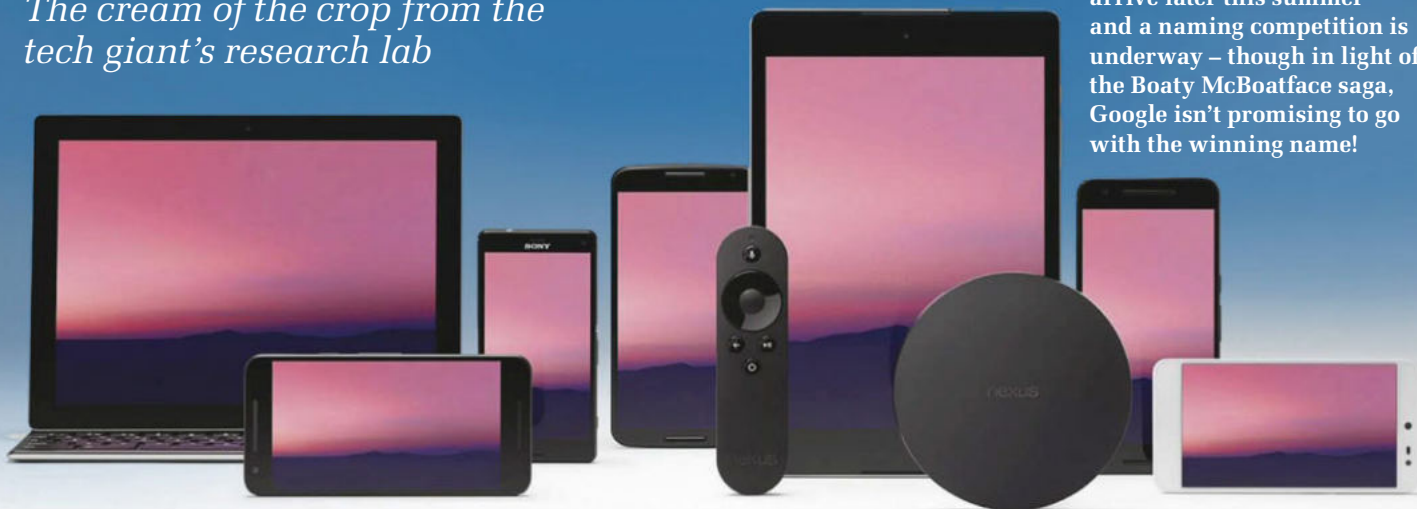
California-based start-up MegaBots has received \$2.4m (£1.64m) in funding to create a global robot-fighting league. The robots involved are hydraulically operated behemoths that weigh in excess of 4,500kg. A human pilot sits inside and directs their robot to physically grapple with another, or fire cannonball-sized paintballs weighing 1.5kg each.

MegaBots has already lined up a battle with rival Japanese company Suidobashi Heavy Industries' Kutaras robot, though a date and venue are yet to be announced. The company has also recruited lawyer Christopher D Brearton, known for his work with the International Olympic Committee and the NBA, with a view to turning these battles into a major international spectator sport.



MY GOODNESS, MY GOOGLE

The cream of the crop from the tech giant's research lab

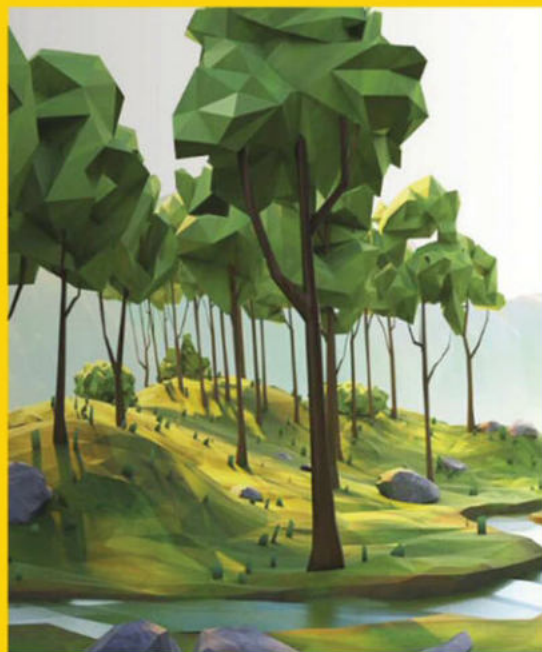


ANDROID N

The latest version of Google's mobile OS has yet to be given a full name, but includes improvements to graphics, security and multitasking capabilities. It's due to arrive later this summer and a naming competition is underway – though in light of the Boaty McBoatface saga, Google isn't promising to go with the winning name!

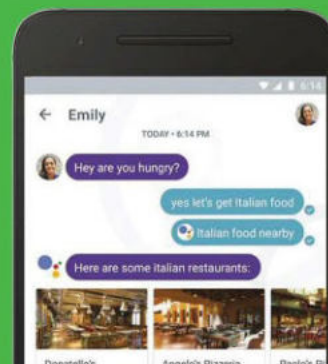
GOOGLE DAYDREAM

Daydream is an operating system for virtual reality headsets, and is built on top of Android N. Users of Daydream-equipped VR devices will be able to access Google apps and services such as YouTube and Google Play without leaving their virtual bubble. Google was showing off Daydream using its own prototype standalone headset at their recent I/O event, but there are no plans, so far, to bring said headset to market.



GOOGLE ALLO

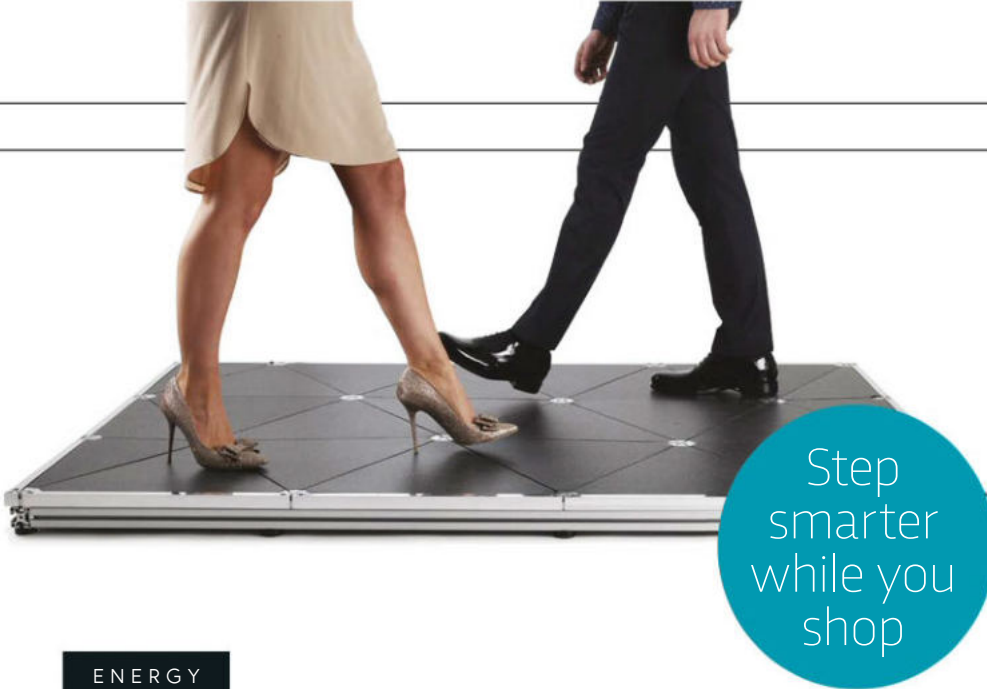
Allo, Google's upcoming smart messaging app, looks to compete with the likes of WhatsApp and Snapchat. There's end-to-end encryption (though you'll need to opt-in to this), and built-in chatbots that will compose generic replies if you're one of those popular types who gets overrun with messages.



GOOGLE HOME & GOOGLE ASSISTANT

Google Home is a sleek, pear-shaped device that allows you to chat with the recently announced Google Assistant, which is Google's answer to Apple's Siri. As well as searching for information and interacting with online services, Google Home can also stream music, control Internet of Things devices, and send and receive voice and text messages. It'll be available later this year.





ENERGY

Power walking

London's Oxford Street is one of the world's top shopping destinations. Which is precisely why it's been selected as one of the first places to benefit from these new power-generating floor tiles from Pavegen.

Pavegen has been making energy-generating tiles for some years now, with over 100 locations worldwide (including Harrods and Heathrow Airport) drawing at least some of their energy from people's footsteps. Tread on a tile and a flywheel underneath rotates to create a current through electromagnetic induction.

However, Pavegen's existing tiles are square, and generate power only if you step right in the middle of them. These new tiles are triangular and generate 5W of power wherever you stand, making them up to 20 times more efficient. Their triangular shape also makes them suitable for installation in less uniform spaces.

As well as over 200 locations on Oxford Street (including the tube station), the tiles will also be deployed in the Westfield Shopping Centre in east London, and at Dupont Circle in Washington DC.

ROBOTICS

The robot that pretends to care



Dr Hiroshi Ishiguro of the Intelligent Robotics Laboratory at Japan's Osaka University built this robot for one purpose: to pretend to listen to you.

The robot is called CommU, and when two or more are placed together, they will simulate people having a conversation. If a human attempts to join in, the robots will smile, nod, and respond to comments by saying things like, "I see" or "interesting point". They won't actually understand what's been said, but will appear to.

This is, of course, an entirely pointless achievement. But the motivation behind the CommU was to try and model the subtle body language and polite niceties that are so important to conversation.

Ishiguro and his team now hope to make robots endowed with *actual* AI seem more 'human' and less intimidating. "AI isn't just about programming and engineering skills," he says. "Equally important for roboticists is an understanding of human psychology and behaviour. One must find a balance between the psychological and the scientific when building androids."

MATERIALS

Touching isn't believing

Researchers at Massachusetts Institute of Technology (MIT) have built a 'materiable tactile display' that can feel, to the touch, like a range of different materials, from rubber to water to silk.

The display is made up of a matrix of columns or pins whose flexibility, viscosity and elasticity can be programmed by the person who is setting it up. Suggested uses for the display include more realistic modelling of landscapes and ecosystems by earth scientists, or the creation of realistic architectural models – and at this stage, that's



probably about as far as it goes. If the technology can be miniaturised and made more affordable, however, the implications for haptic feedback systems for VR are obvious. Further down the line, the display could even be used to create shape-shifting furniture whose very texture can be altered via a smartphone app.

WANTED!

QUICK FLASH

IMPOSSIBLE PROJECT I-1

Polaroid-style photography is dragged into the 21st Century with the arrival of this instant camera that combines cutting-edge tech with retro styling. The ring flash that surrounds the lens doubles as the user interface, with its lights indicating battery life and how many shots you have remaining. More advanced features are accessed via a smartphone app. The camera uses Impossible's I-type film, which the company has been manufacturing since taking over an old Polaroid film factory in 2008.

£269.99 (camera plus three packs of film), uk.impossible-project.com



A LOAD OF HOT AIR?

DYSON SUPERSONIC



Dyson is on a roll with new product launches right now. Hot on the heels of its air purifier and robot vacuum comes the Supersonic hairdryer, which makes use of similar technology to the company's bladeless desktop fans. At just 618g it's light and manoeuvrable, there are four heat settings and three speed settings, and Dyson suggests it will dry your hair up to eight times faster than a conventional hairdryer. It's not cheap, mind...

£300, dyson.co.uk

THREE SIDES GOOD

NEPSU TRIANGLE

Compatible with most leading multiroom systems, this stylish speaker accepts audio input via Wi-Fi, Bluetooth or a 3.5mm stereo jack. At the time of writing, it was 84 per cent of the way to its Indiegogo funding target. The Nepsu Triangle can stand upright on a shelf or desk, be hung in an awkward corner, or wall-mounted. It even features interchangeable faceplates, power cords and acoustic meshes so you can match it to your decor. There's also a built-in mic if you want to use it to make and receive hands-free calls, though this is detachable.

\$360 (£250 approx) each, nepsu.com



GEEK CHIC

ODD MATTER NODE LAMP

The perfect home accessory for electrical engineers, the stylish Node lamp from Odd Matter Studio is built to look like its own circuit diagram, with domed shades made from a plaster-resin composite that resemble the bulb symbols on a schematic drawing. To turn the light on, you simply tilt its folding arm (which is made of copper coils) to complete the circuit; to turn it off, tilt it back to break the circuit. [ETBC, oddmatterstudio.com](#)



HOT WHEELS

GEOORBITAL WHEEL

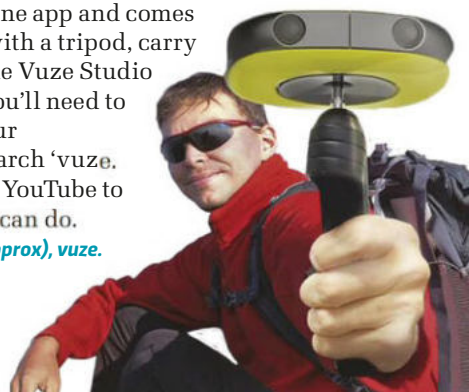
Someone's only gone and *actually* reinvented the wheel, haven't they? Designed by former SpaceX and Ford engineers, the imaginatively named GeoOrbital Electric Bike Wheel turns any bicycle into an electric bike, and comes in two different sizes to fit, according to its makers, 95 per cent of all adult bicycles. Once fitted, the wheel's 36V lithium-ion battery will enable you to cruise along at 32km/h (20mph) for up to 80km (50 miles) on a single charge. And all without breaking a sweat! [\\$950 \(£658 approx\), geoo.com](#)

ALL-SEEING EYE

VUZE VR CAMERA

This \$799 camera from Vuze is currently the cheapest 3D, 360°, 4K video camera on the market by some considerable margin, bringing the creation of engaging virtual reality content within reach of a much greater proportion of filmmakers. The eight-camera device is controlled via a smartphone app and comes complete with a tripod, carry case and the Vuze Studio software you'll need to process your footage. Search 'vuze, camera' on YouTube to see what it can do.

[\\$799 \(£550 approx\), vuze.camera](#)



APP FEED



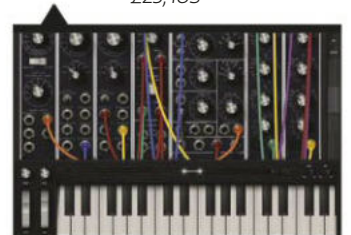
Dark Sky

Weather app *Dark Sky* is now on Android. Basic info is free, but to get the hyper-local forecasts that make the app popular, you'll have to subscribe. [Free/\\$3 annual subscription, Android](#)



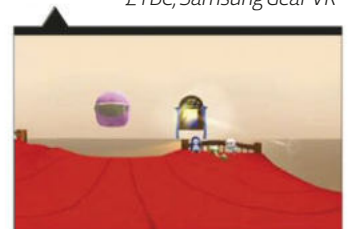
Moog Model 15

Experience the joys of making music with this app, which emulates Moog's Model 15 synth – for a far smaller outlay than the \$10K asking price of the real thing! [£23, iOS](#)



BedTime VR Stories

This app for Gear VR means that parents who work away from home can still read their kids a story at bedtime – wherever they happen to be. [ETBC, Samsung Gear VR](#)



Performance without compromise



Spectre Lite

- AMD FX-4300
- ASUS® M5A97 R2.0
- 8GB HyperX FURY RAM
- 2GB NVIDIA® GeForce® GTX 950
- 1TB Hard Drive
- Corsair 350W PSU
- Windows 10
- 3 Year Standard Warranty

THIS SPEC FROM **£499***



Gladius 900

- Intel® Core™ i5-6600K
- ASUS® Maximus VIII Hero
- 8GB HyperX FURY RAM
- 2GB NVIDIA® GeForce® GTX 960
- 1TB Hard Drive
- Corsair 450W PSU
- Windows 10
- 3 Year Standard Warranty

THIS SPEC FROM **£899***



Vitrum

- Intel® Core™ i5-6600K
- ASUS® Z170-E
- 16GB HyperX FURY RAM
- 4GB NVIDIA® GeForce® GTX 970
- 400GB Intel® 750 PCIe SSD
- 1TB Hard Drive
- Windows 10
- 3 Years Warranty

THIS SPEC FROM **£1,199***



Glacier

- OC Intel® Core™ i7-6700K
- ASUS® Maximus VIII Hero
- 16GB Corsair Vengeance RAM
- 6GB NVIDIA® GeForce™ GTX980Ti
- 400GB Intel® 750 PCIe SSD
- 2TB Hard Drive
- Windows 10
- 3 Years Warranty

THIS SPEC FROM **£1,799***



14" Enigma VI

- Intel® Core™ M CPUs
- Intel Integrate Graphics
- Ultra thin: Just 15.6mm!
- Full HD IPS Screen
- Up to 7.5 Hours Battery
- Wireless as standard
- Windows 10
- 3 Year Standard Warranty

THIS SPEC FROM **£409***



15.6" Octane II

- 6th Gen Intel® Core™ CPUs
- NVIDIA® GeForce™ Graphics
- NVIDIA® G-SYNC™ Option
- Full HD IPS Screen
- Thunderbolt™ 3
- Wireless as standard
- Windows 10
- 3 Year Standard Warranty

THIS SPEC FROM **£1,119***

Order your system now with PC Specialist



/pcspecialist



@pcspecialist

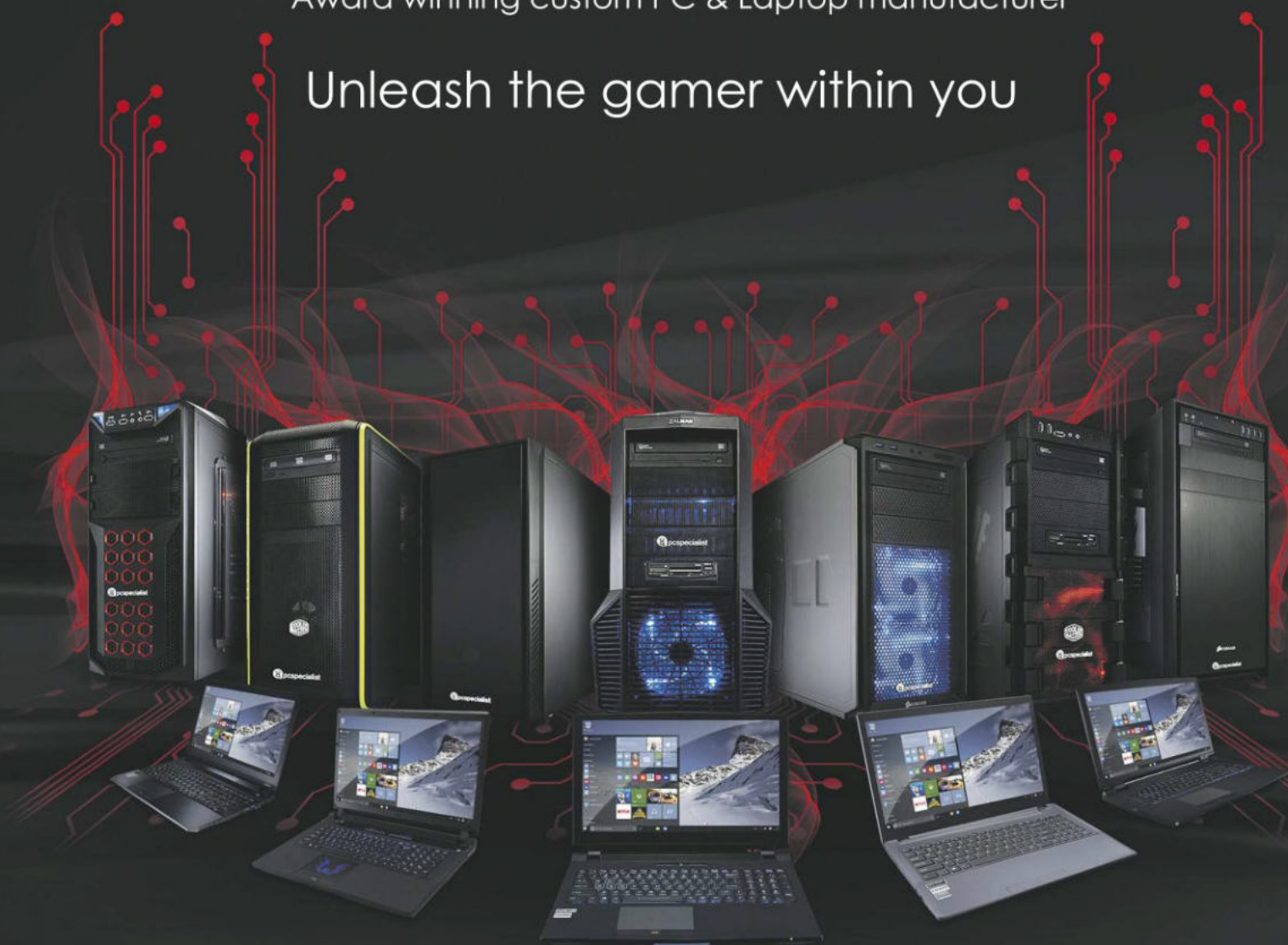
Some features require Windows 8.1. Update available through Windows Store. Internet access required; fees may apply. Microsoft, and Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

* Prices are including VAT and are correct at the time of printing, but subject to change.



Award winning custom PC & Laptop manufacturer

Unleash the gamer within you



Vulcan 440

- Overclocked Intel® Core™ i7-4790K
- ASUS® Maximus VII Ranger
- 16GB HyperX FURY RAM
- 4GB NVIDIA® GeForce® GTX 980
- 500GB Samsung EVO 850 SSD
- 2TB Hard Drive
- Windows 10
- 3 Year Standard Warranty

THIS SPEC
FROM

£1,499*

Quality builds at a low price
Always

GET A FURTHER £15 OFF WITH THIS EXCLUSIVE VOUCHER CODE:

BBF57

ORDER ONLINE NOW

0333 011 7000

www.pcspecialist.co.uk



SPACE SPECIAL

JULY 2016

EDITED BY EMMA BAYLEY



DR CHRISTIAN JARRETT

Christian is a psychology and neuroscience writer. His latest book is *Great Myths Of The Brain*.



DR ALASTAIR GUNN

Alastair is an astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester.



PROF ROBERT MATTHEWS

Robert is a physicist and science writer. He's visiting professor in science at Aston University.



DR PETER J BENTLEY

Peter is a computer scientist and author who is based at University College London. His latest book is *Digitized*.



LUIS VILLAZON

Luis is a freelance science and tech writer with a BSc in computing and an MSc in zoology from Oxford University.



DR MARK LORCH

Mark is a senior lecturer at the University of Hull, where he teaches chemistry and science.



DR ELIZABETH PEARSON

Elizabeth is *Sky At Night Magazine's* news editor and has a PhD in extragalactic astrophysics.



COLIN STUART

Colin is a science writer and astrophysicist. His most recent book is *Physics In 100 Numbers*.



DR STUART CLARK

Stuart is an astronomy writer with a PhD in astrophysics. His latest book is *The Unknown Universe*.



SHANNON WALKER

Shannon is a scientist and NASA astronaut who went to the International Space Station in 2010.

HOW DO ASTRONAUTS GO TO THE LOO? P38

WHO WILL REACH THE MOON NEXT? P40

WHAT DOES MARTIAN WATER TASTE LIKE? P43

WHAT WILL WE LEARN FROM THE JUNO MISSION? P44

**HOW HIGH COULD YOU JUMP ON OTHER
SOLAR SYSTEM BODIES?** P48

WHERE ARE ALL THE ACTIVE SPACECRAFT? P50

WHY DO ASTRONAUTS LOVE PRAWN COCKTAIL? P56

WHICH ANIMALS HAVE VISITED SPACE? P58

COULD PLUTO BECOME A PLANET AGAIN? P60



How 'intelligent' could we make space probes?

One of our biggest problems with space probes and explorer robots is that it takes time to talk to them. Depending on the position of Earth and Mars, it can take anything from four to 24 minutes for a signal to cross the void between them. It currently takes more than 17 hours for a signal to reach Voyager 1, which is our most distant probe. That may be much too slow to warn it about an impending threat. Adding some intelligence to make them more autonomous would enable them to handle such situations by themselves. An explorer robot could avoid driving into a hole, or a probe could reconfigure its electronics and recover from damage. If we make them clever enough, maybe one day a probe might be the first Earth entity to hold a conversation with alien life. **PB**

Probes like Rosetta still need to receive their instructions from controllers on Earth

How do astronauts go to the loo?

For 'number ones', they use a funnel attached to a hose that is connected to a fan that generates suction. For solids, they 'dock' themselves carefully over a hole about the size of a drain pipe and clamp their feet into the foot restraints. Waste is caught in an individual bag liner, which they seal after use and the package is sucked into a collection drum. **LV**



Does zero-g affect sleep and dreaming?

Astronauts in microgravity environments such as the International Space Station (ISS) have to strap themselves into a secured sleeping bag, otherwise they'd just float about. Sleep tends to be more disturbed on space missions than on Earth – this could be due to microgravity or to other factors such as noise, excitement, stress and jet lag type problems (there are 15 dawn and dusk cycles a day on the ISS). Astronauts report having dreams but seem to need less sleep in space – around six hours rather than seven or eight. One theory is that this may be due to the physical ease of moving in microgravity. **q**



Astronauts strap into sleep restraints when it's time to get some well-earned rest

Why don't more planets have rings?

The gaseous outer planets all have rings, whereas the small, rocky inner planets do not. Scientists aren't sure how these rings came about. They may have assembled from leftover material from the planet's creation, or could be the remains of a moon that was destroyed by an impact or broken apart by the gravitational force of the parent planet.

As only the gas giants have rings, scientists think the ring-forming process may be related to the same mechanism that resulted in gas giants forming in the outer Solar System, and rocky planets in the inner Solar System. The energy given off by the infant Sun expelled most of the light gases and other volatile molecules into the outer regions of the Solar System, leaving the heavier elements to form rocky inner planets. This process also seems to have made it easier for the outer planets to form moons. So, the combination of large gravitational forces, the existence of volatile materials such as ices, and the shepherding of material by numerous moons probably means the outer planets were more likely to form and keep planetary rings. **AG**

How do chemical reactions occur in the cold of space?

The temperature of objects in space varies massively. A sungrazer comet might experience millions of degrees centigrade as it hurtles around our star, but when it swings back out to the edges of the Solar System its surface will plummet to -220°C .

In general, reaction speed is closely linked to temperature, the rule of thumb being the rate of reaction halves for every 10°C drop. So a reaction that takes one second on that comet just as its ice surface melts might then take 1×10^{67} years (that's a one with 67 zeroes after it) out in the Oort Cloud. However, there are other sources of energy that can power reactions: high-energy cosmic rays or ultraviolet light from a nearby star can give chemicals enough energy to react at less astronomical timescales. **ML**

EUROPE

Ever since Johann-Dietrich Woerner became director general in 2015, the European Space Agency (ESA) has been one of the most vocal bodies calling for us to return to the Moon. Woerner himself put forward the idea of building a permanent base on the Moon (concept pictured). He suggested it could be located in the Aitken Basin on the far side of the Moon.

Astronauts from various countries and agencies would be able to use the base to work together towards mutual goals, he says. So far, however, little money has been committed to the idea, but things could change later in the year when the agency decides its priorities and allocates its budget in its Ministerial Council meeting.



CHINA

On 14 December 2013, China became a true contender in the race to put humans back on the Moon when the country successfully landed its Jade Rabbit rover on the lunar surface. The rover operated for 42 days, and although well short of the planned three months, it was still a major boost for the Chinese exploration programme.

The Chinese National Space Administration (CNSA) is now working on its next exploration mission. Dubbed Chang'e 4, the mission will feature a lander and rover and is scheduled to touch down in the Aitken Basin near the end of 2018. If successful, it will be the first landing on the Moon's far side. CNSA is also developing a powerful new rocket, the Long March-9 (pictured), that it says could potentially take humans to the Moon sometime in the 2030s.



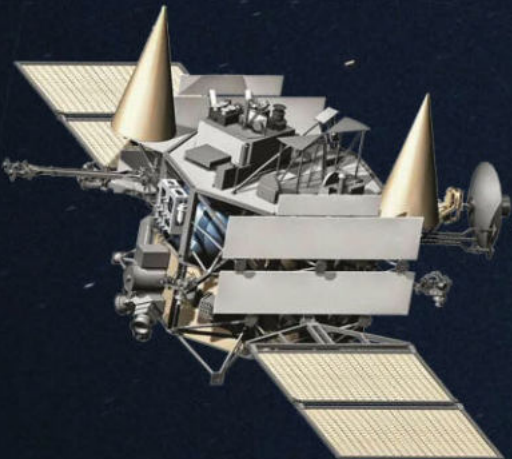
WHO REACH MOON

No human has set foot on the lunar surface since NASA astronaut Eugene Cernan re-entered the Challenger module as part of the Apollo 17 mission in 1972. Now, after more than four decades of inactivity, interest in putting humans back on the Moon is finally heating up again. But who will get there first?

RUSSIA

In May 2014, Russian newspaper *Izvestia* published a government document purported to show that the Russian space agency, Roscosmos, was drawing up plans for a manned Moon landing in 2030. Its ambitions were confirmed in October 2015 when Vladimir Solntsev, head of Roscosmos, told reporters that the country plans to send a crew to the Moon in 2029.

Meanwhile, the Russians are ramping up their robotic exploration programme. Roscosmos is currently working on a range of orbiters and landers called Luna-25, Luna-26 (concept pictured) and Luna-27. The idea is that the landers will explore the lunar south pole, prospecting for resources such as minerals and water ice that could be used to sustain a human outpost.



WILL THE NEXT?

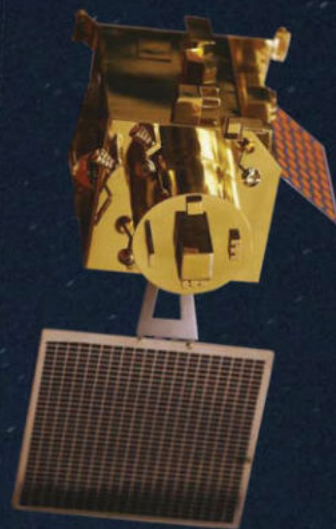


JAPAN

The Japanese Aerospace Exploration Agency (JAXA) has sent two missions into lunar orbit, 1990's Hiten and 2007's SELENE. It's currently working towards making its first lunar landing attempt. JAXA's original plans were for SELENE-2, a large 1,000kg lunar lander and 200kg rover. But JAXA has now scaled down its plans. The new mission, dubbed Smart Lander for Investigating the Moon (SLIM), is a smaller, 120kg craft (pictured) that will aim to demonstrate high-precision landing on the Moon's surface in 2018.

INDIA

Following the success of its first lunar probe, Chandrayaan-1 (pictured) in 2008, the Indian Space Research Organisation announced a follow-on mission. Whereas Chandrayaan-1 carried additional instruments provided by NASA, ESA and the Bulgarian Aerospace Agency, Chandrayaan-2 was meant to be a collaboration with Russia. When the Russians failed to deliver the promised lander in 2013, India decided to go it alone. The mission's current launch date is set for 2018, this time carrying an all-Indian payload of orbiter, lander and rover.



USA

NASA has earmarked Mars as its next big target for manned missions. But without the rest of the world to help, it's going to be almost impossible to send anyone there. This fact has not been missed by veteran astronaut Buzz Aldrin, who has urged the space agency to refocus on returning to the Moon.

In December 2018, NASA plans to launch the Exploration Mission 1, an uncrewed test of their Orion astronaut capsule (pictured) in which the craft will loop around the Moon before returning to Earth. All being well, a crewed capsule will follow in 2023. Should the mission prove a success, the astronauts will be the first humans to see the far side of the Moon with their own eyes since Apollo 17 in 1972.

Does Earth have a second moon?

There is only one permanent natural object that orbits the Earth: the Moon. Several small asteroids are 'quasi-satellites' of the Earth; from our perspective they appear to follow a loop around our planet, but they are not actually orbiting us. Occasionally, Earth

captures an asteroid in a temporary orbit and these can be considered moons or 'minimoons'. One such object, the asteroid 2006 RH120, was a car-sized 'moon' of Earth that orbited from September 2006 to June 2007. **AG**

An asteroid will occasionally be captured into Earth's orbit – but only temporarily

IN NUMBERS

716

The number of rotations made each second by the fastest-spinning neutron star.

2,100

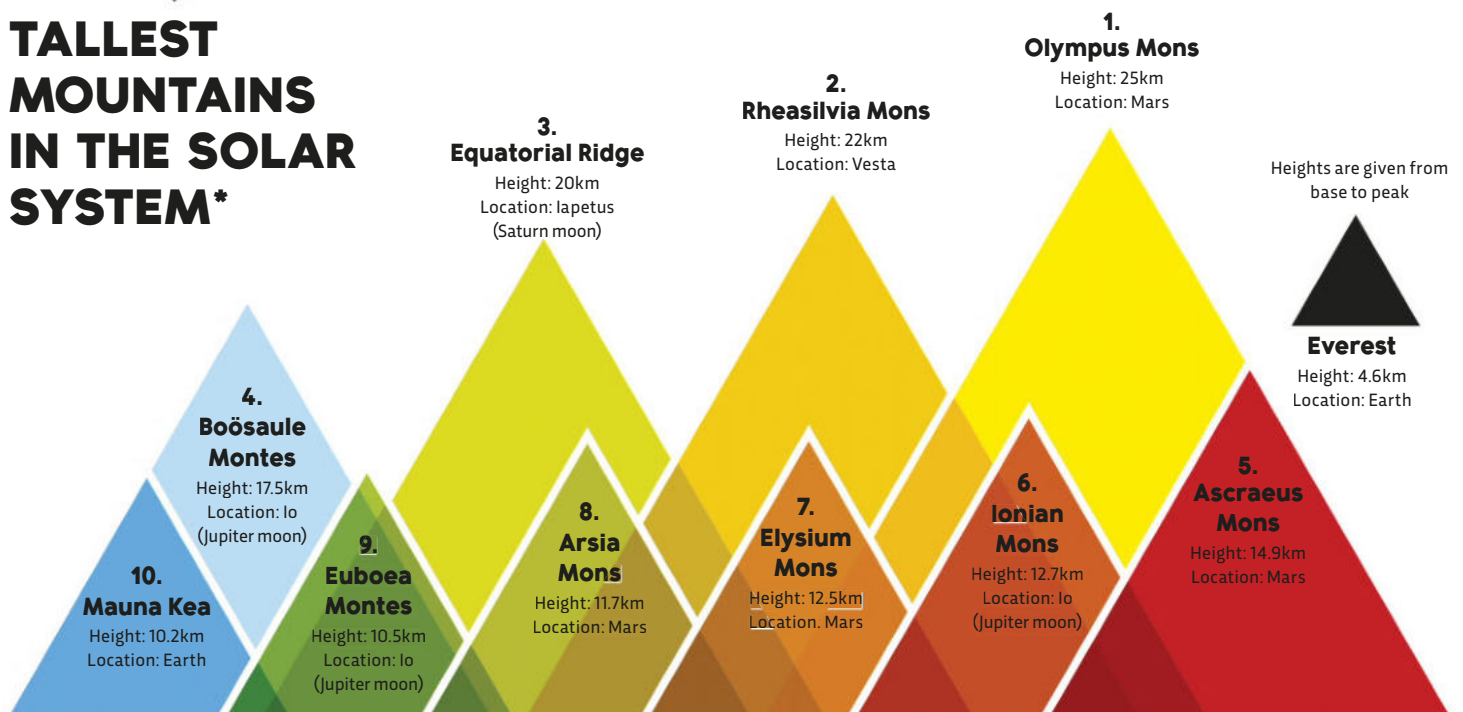
The speed, in km/h, of recorded winds on Neptune.

67

The number of known moons that orbit Jupiter – but there may be more.

TOP 10

TALLEST MOUNTAINS IN THE SOLAR SYSTEM*



Artistic rendering of the theoretical planet nine



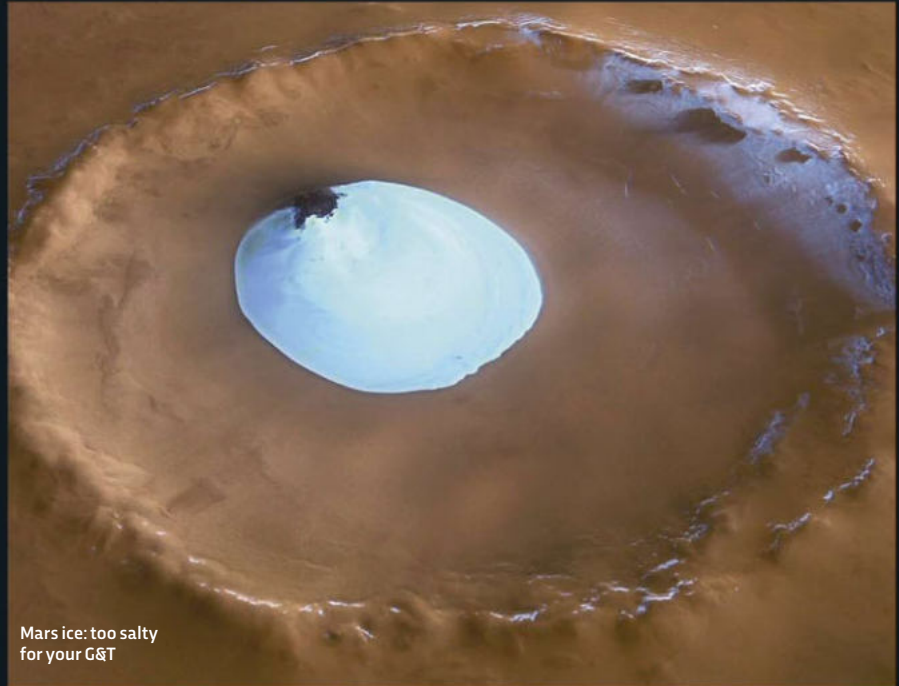
Could there be a planet nine?

It is certainly a possibility. Since we haven't discovered a ninth planet yet, we can be reasonably sure that if it exists it is quite distant from the Sun. Recently, astronomers analysed the motions of objects at the furthest edge of the Solar System and noticed something peculiar. The elliptical orbits of many of these objects all seem to line up in the same direction. This could be explained if a sizeable ninth planet exists. This as-yet-unproven planet must orbit at least 20 times further away than Neptune and could be 10 times the mass of the Earth. **AC**

What does Martian water taste like?

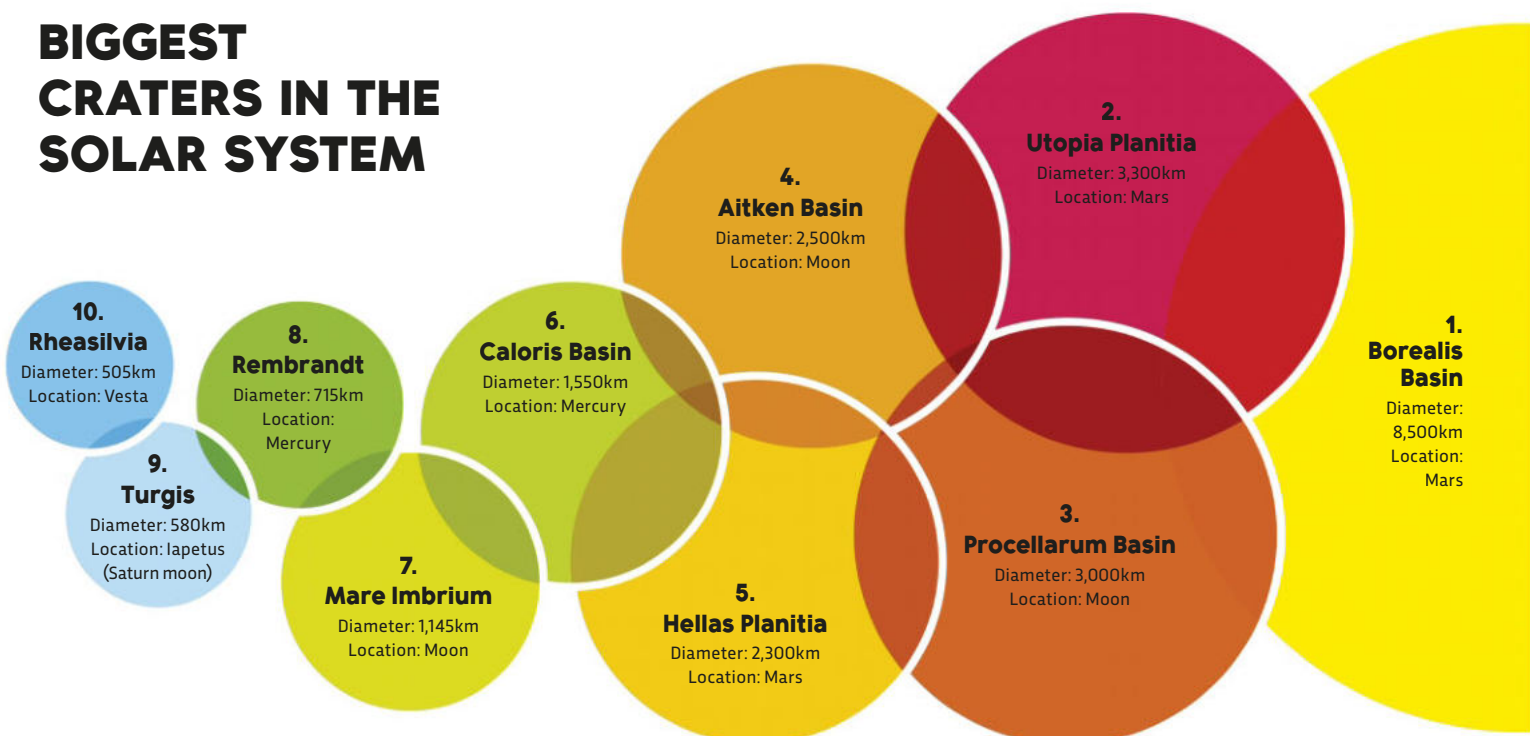
Most of Mars's water isn't present as liquid: it's ice, mixed in with the soil. Mars has such low atmospheric pressure that pure water ice sublimates directly from solid to gas without ever melting into liquid. There is evidence

that the Red Planet may occasionally have some liquid water, but it would be undrinkably salty. If you distilled the water inside your pressurised habitat though, it would be quite safe to drink. **LV**



Mars ice: too salty for your G&T

BIGGEST CRATERS IN THE SOLAR SYSTEM



What will we learn from the Juno mission?

On 4 July 2016, NASA's Juno spacecraft will complete its 2.8 billion kilometre journey to the king of the Solar System: Jupiter. For centuries the gas giant has remained a mystery, shrouded in a thick atmosphere of hydrogen and helium. But now Juno will look beyond the upper layers, right into the planet's heart.

Juno will map the gravitational and magnetic structure of the planet, allowing researchers to test theories about how its atmospheric gases behave under the extreme pressure of Jupiter's interior. Once Jupiter's current construction is known, it will then be possible to work out how, when and potentially where in the Solar System the planet first formed.

The NASA mission launched into space from Cape Canaveral on 5 August 2011 aboard an Atlas V rocket, but this alone could not deliver enough thrust to reach Jupiter. On 9 October 2013 the spacecraft performed a slingshot around the Earth, using our planet's gravity to accelerate to a final speed of 11km/s.

Once the craft arrives, Juno will perform 37 highly elliptical orbits over the planet's poles. Its path will pass less than 5,000km above the upper clouds before swinging out to a distance of millions of kilometres and back over the course of 14 days.

Once its mission is done, the probe will be deorbited in 2018, burning up in Jupiter's atmosphere to avoid any contamination of its moons – there are over 60 of them – which are thought to be our best chance of finding life outside our planet. ☉

SOLAR PANELS

Juno will be the most distant spacecraft to be powered by solar energy. As Jupiter receives 25 times less sunlight than the Earth, it requires three 2.65 x 8.9m solar panels to generate the 450W needed to power Juno.

JUNOCAM (hidden in this image)

The only camera on the craft, JunoCam, will take colour images of the planet. However, the task of choosing what targets to photograph and processing the final images will be done by the public. Go to missionjuno.swri.edu/junocam to get involved.



GRAVITY SCIENCE

Massive structures within Jupiter create fluctuations in the planet's gravitational field that will pull on Juno as it orbits, altering its speed. Gravity Science will measure these velocity changes, creating a gravity map from the readings.

JOVIAN ENERGETIC PARTICLE DETECTOR INSTRUMENT (JEDI)

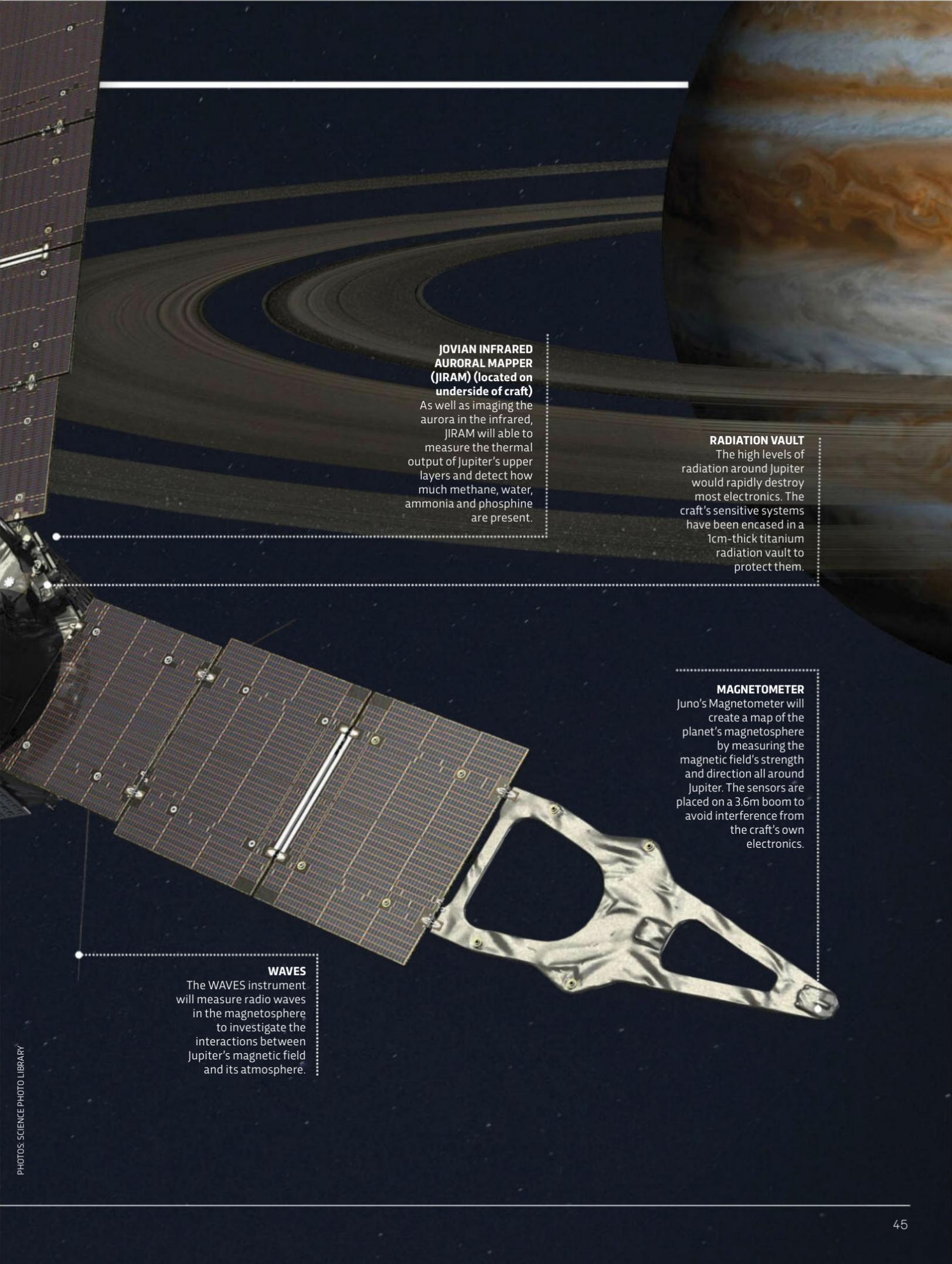
One of many particle detectors, JEDI will detect the highest energy particles around Jupiter. It will also investigate X-rays emitted from the planet's poles that do not appear to be related to the aurora.

JOVIAN AURORAL DISTRIBUTION EXPERIMENT (JADE)

The three JADE detectors will detect the particles and ions caught in Jupiter's magnetic field that cause the aurora.

MICROWAVE RADIOMETER (MWR)

By measuring the microwave emissions from Jupiter, the MWR will discern the thermal profile of Jupiter's atmosphere, helping to interpret how gas circulates on the planet.

A detailed illustration of the Juno spacecraft in orbit around Jupiter. The spacecraft is shown from a side-on perspective, with its large solar panel array extended. The planet Jupiter, with its characteristic orange and white bands, is visible in the upper right corner. The background is a deep blue space filled with stars. The spacecraft's body is dark, and the solar panels are a grid of small, square cells. The Juno probe is positioned in the center-left of the frame, with its boom extending towards the right. The planet Jupiter is partially visible on the right side of the image, showing its iconic cloud patterns. The overall scene is set against a dark, starry background, emphasizing the vastness of space.

**JOVIAN INFRARED
AURORAL MAPPER
(JIRAM) (located on
underside of craft)**

As well as imaging the aurora in the infrared, JIRAM will be able to measure the thermal output of Jupiter's upper layers and detect how much methane, water, ammonia and phosphine are present.

RADIATION VAULT

The high levels of radiation around Jupiter would rapidly destroy most electronics. The craft's sensitive systems have been encased in a 1cm-thick titanium radiation vault to protect them.

MAGNETOMETER

Juno's Magnetometer will create a map of the planet's magnetosphere by measuring the magnetic field's strength and direction all around Jupiter. The sensors are placed on a 3.6m boom to avoid interference from the craft's own electronics.

WAVES

The WAVES instrument will measure radio waves in the magnetosphere to investigate the interactions between Jupiter's magnetic field and its atmosphere.

● With a diameter of 140,000km and the mass of 318 Earths, Jupiter dominates our Solar System. In fact, its gravitational influence is so enormous that it affects the orbits of all the planets. It is thought that the planets of the Solar System originally formed in a slightly different configuration, but Jupiter's huge mass upset the gravitational balance, causing it and Saturn to migrate inwards, while Neptune was flung further out in the Solar System. And that's why Juno's mission is so important – it is impossible to understand how our planetary system formed without knowing more about this colossus.

But our current understanding of Jupiter is limited. So far, all we have been able to see is the top few hundred kilometres of the atmosphere. Here, the planet has remained remarkably stable; the striped cream and brown bands that ring Jupiter have barely shifted in latitude during the centuries we have been observing the planet.

No one knows what keeps these bands in motion, how deep they go, what causes their colouring or what's behind the great vortices that periodically appear within them. However, by peering through the clouds, Juno will finally allow us to answer at least some of these questions. By measuring the gravitational field of Jupiter, researchers will be able to find areas of high density deep within the planet, and discovering the subtleties of the magnetic field will give an insight into the workings of the inner core. Together with other measurements of the surface layers, Juno will unveil the structures hidden beneath the clouds of the Solar System's biggest enigma. **EP**

COMPOSITION

Though much of Jupiter is hydrogen (90 per cent) and helium (10 per cent), Juno will determine the levels of trace gases such as ammonia and water. Jupiter's atmosphere has remained mostly unchanged since its formation, so learning its composition will tell us much about the primordial Solar System that created it.

ATMOSPHERE

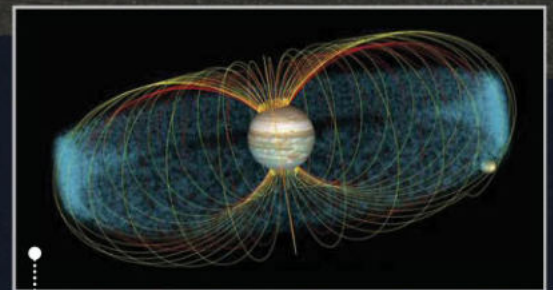
There is disagreement as to whether Jupiter's upper layers sit over a stable core, or if there is no clear boundary and the two mix together freely. Juno's gravity maps will help detect which structure exists.

RINGS

Jupiter is surrounded by faint dusty rings, believed to be material ejected from some of its moons.

VORTICES

Caught in Jupiter's light-coloured zones are rotating vortices measuring thousands of kilometres across. These storms can last from as little as a few days to years or even centuries. Juno will look deep into their depths by imaging them in the infrared.



MAGNETOSPHERE

Jupiter's magnetic field, or magnetosphere, is one of the largest structures in the Solar System, extending three million kilometres around the gas giant. It's powered by electric currents deep in the interior, but Juno's magnetic map will determine if it is a solid core or the motion of highly pressurised 'metallic' hydrogen that generates these currents.



DON'T MISS
THE SKY AT NIGHT
BROADCAST ON 10 JULY,
10PM

FOUR

BELTS AND ZONES

Moving in opposite directions, the cream coloured zones and darker brown belts are separated by fast-flowing winds, called jets. Juno will attempt to discover what keeps the belts in motion.

CORE

It's uncertain whether Jupiter formed from a collapsing cloud of gas, like a star, or if its atmosphere coalesced around a solid core. Studying the planet's gravity profile will uncover whether such a core exists.

GREAT RED SPOT

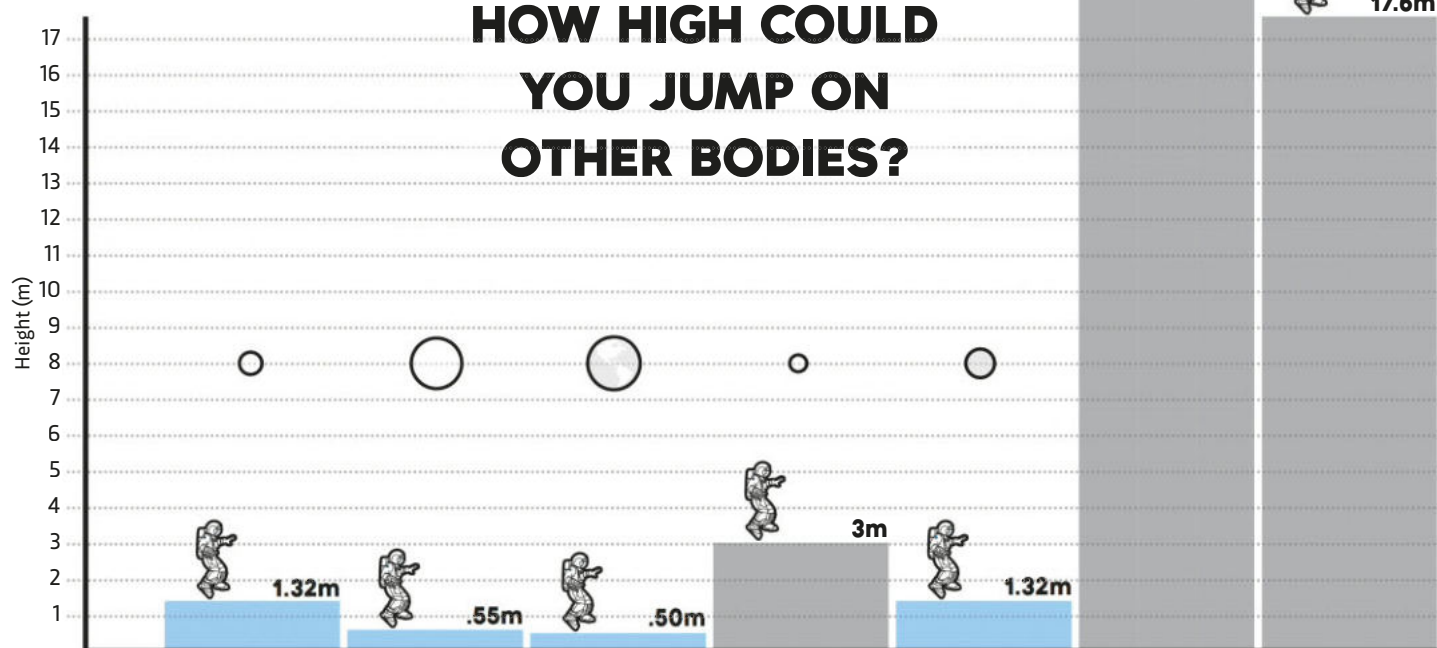
Jupiter's largest storm, the Great Red Spot, is big enough to swallow the Earth three times over, yet the force driving it is unknown. Juno's gravity measurements will allow researchers to find out how deep the maelstrom extends, hopefully determining the source of its energy.

AURORA (not visible on this image)

Like the Earth, Jupiter has aurora. Particles become caught in the magnetic field and then collide with the atmosphere, emitting light. On Jupiter though, the aurora are most vibrant at ultraviolet wavelengths. Several of Juno's instruments will study the phenomena.

THE THOUGHT EXPERIMENT

HOW HIGH COULD YOU JUMP ON OTHER BODIES?



Mercury

Venus

Earth

Moon

Mars

Phobos

Ceres

Surface gravity

0.378G

0.91G

1.0G

0.166G

0.379G

0.00059G

0.0284G

Average person

30.2kg

72.8kg

80kg

13.3kg

30.3kg

0.0472kg

2.272kg

IN NUMBERS

90

per cent

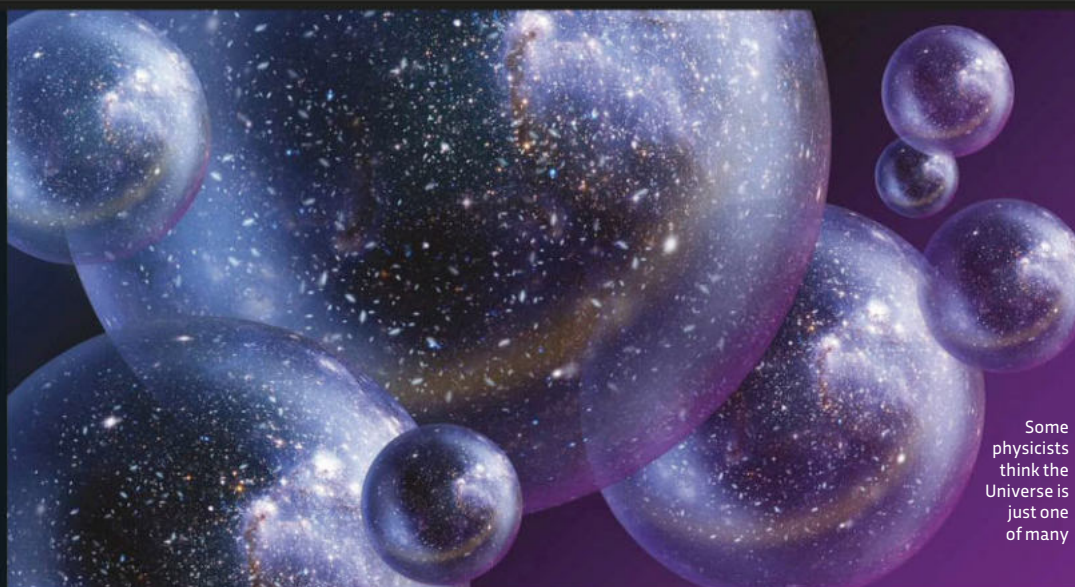
The amount of sunlight reflected by Enceladus. It is the most reflective object in the Solar System.

-13°C

The maximum temperature of the coolest known star.

110

The speed, in km/s, at which the Andromeda Galaxy is approaching the Milky Way.



Some physicists think the Universe is just one of many

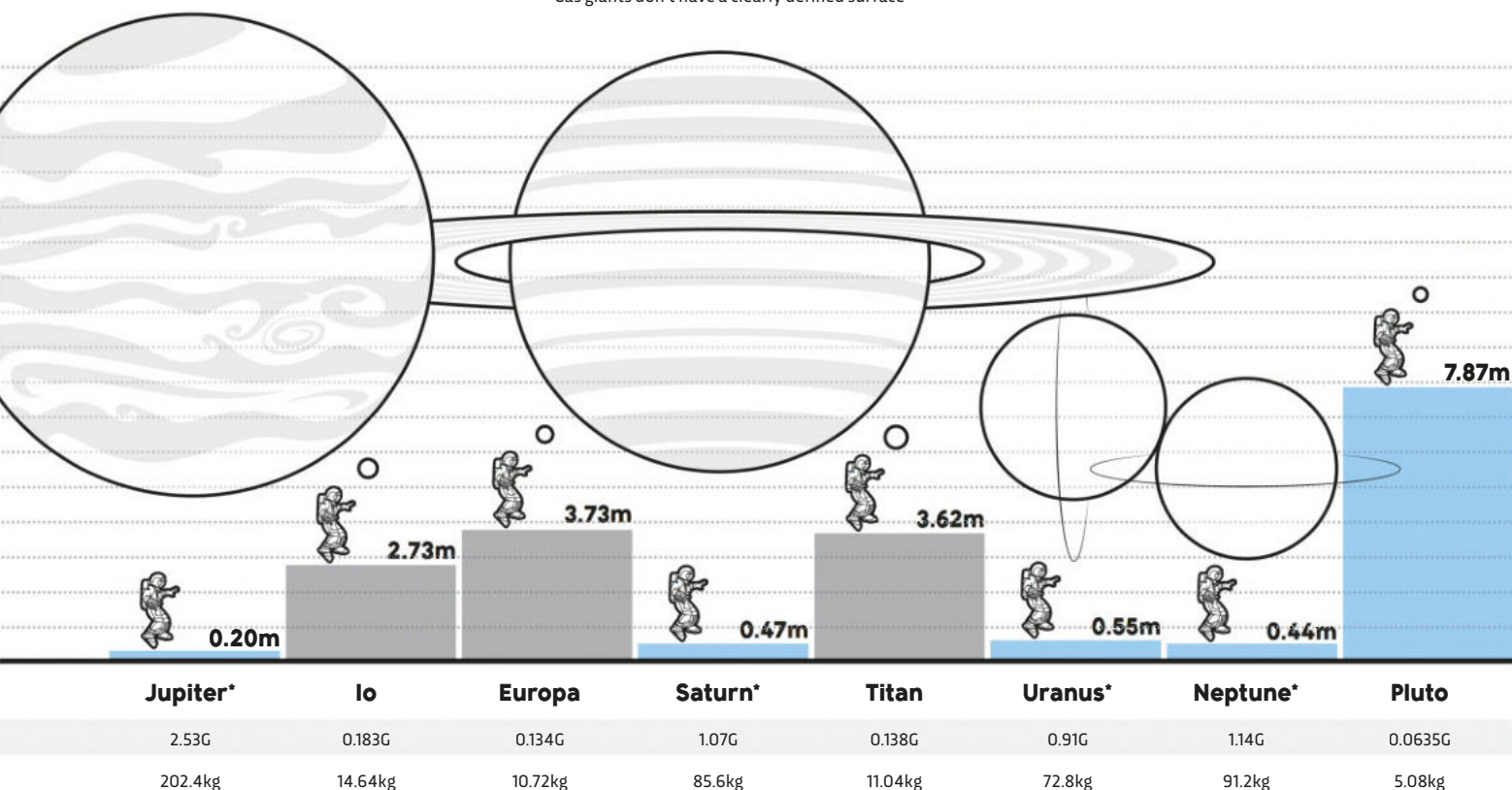
Could we ever detect other universes?

The idea that the Universe is just one of many, making up one, truly infinite 'multiverse' is among the most intriguing – and controversial – theories in modern physics. It's based on attempts to find the one true 'Theory of Everything' (ToE) that describes all the particles and forces making

up reality in a single set of equations. Some attempts to create the ToE suggest that there are myriad different universes beyond our own, each with different laws of physics. According to some theorists, these differences may reveal the existence of universes neighbouring our

own. Exactly how they'll be revealed is unclear, but one possibility is via distortions in the heat left from the Big Bang. This has been mapped with exquisite precision, and may contain telltale patterns consistent with the lurking presence of another universe. **RM**

*Gas giants don't have a clearly defined surface



Why is the Moon moving away from us?

Almost 300 years ago, astronomer Edmond Halley first suspected the Moon was receding, after studying records of ancient eclipses. His suspicions were confirmed in the 1970s, when laser beams bounced off mirrors put on the Moon showed that it is moving away from Earth at the rate of 3.8cm per year.

It's driven by the effect of the Moon's gravity on the Earth. Tides raised in the oceans cause drag and slow the Earth's spin-rate. The resulting loss of angular momentum is compensated for by the Moon speeding up, and thus moving further away.

But there's a problem. At this rate of recession, the Moon must have separated from Earth 1.5 billion years ago – far more recently than geological evidence suggests.

Creationists use this to question the scientific account of the origin of the Earth and Moon. However, astronomers say that the recession rate will have been slower in the past because of continental drift, which altered the size and depth of the oceans and thus the amount of tidal drag. Taking this into account pushes the date back by several billion years – in line with geological evidence. **RM**

Mirrors placed on the Moon allow astronomers to measure its distance from Earth by bouncing lasers off the reflective surfaces



What's the oddest thing sent into space, and what did it cost?

My favourite is probably the brainwaves of Ann Druyan. This EEG recording was included on the golden records that were sent to space aboard Voyager 1 and 2 in 1977. Ann Druyan is a science writer and TV producer who was part of the team that chose the sounds and music that went on the record. During the recording, Druyan had a list of topics to think about, including Earth history, difficulties affecting humans and what it is like to fall in love. The Voyager program cost £600m but the brainwave recording was effectively free. My second favourite is the Lego figure of Galileo, which will arrive at Jupiter aboard Juno. **LV**



From left to right: Galileo, Juno (Roman goddess) and Jupiter (Roman god) are embodied in Lego on the Juno spacecraft

WHERE ARE ALL THE ACTIVE SPACECRAFT IN OUR SOLAR SYSTEM?

Since Sputnik 1 was launched in 1957, humans have sent thousands of spacecraft into the cosmos. There are currently around 50 active* craft in our Solar System. Here's where they are and what research they are doing

*not including miniaturised, amateur or commercial craft

AKATSUKI

Many mysteries abound around Venus, and Akatsuki is the latest probe to take a closer look. It will search for lightning in the Venusian atmosphere, study the abundance and distribution of key gases and look at how the planet's heat is distributed in the lower atmosphere. And that heat is significant – Venus is the hottest planet, even though it isn't closest to the Sun. Names and competition went along for the ride on engraved aluminium plates.

58 million km from Sun

108 million km from Sun

STEREO A/B (SOLAR TERRESTRIAL RELATIONS OBSERVATORY)

Building a 3D picture of storms erupting from the Sun. STEREO A is active, but contact was lost with STEREO B in 2014.

AKATSUKI

Studying Venus's atmosphere and cloud decks. Entered orbit in December 2015.

SPITZER SPACE TELESCOPE

Taking infrared images of galaxies and nebulae. Most instruments have stopped working.

KEPLER

Detecting planets outside our Solar System, particularly those like the Earth.

KEPLER

Kepler is the king of exoplanet hunters. Since its launch in 2009, this space observatory has uncovered 2,300 alien worlds by looking for small dips in the brightness of stars as planets ghost in front of them. From these 'transits', astronomers can work out the size of the planet and how far it orbits from its star – crucial in working out its temperature. Kepler's haul includes Earth-sized planets with temperatures friendly to liquid water, a world with two Suns, and a solar system with multiple planets squeezed closer to their sun than Mercury is to ours.

LAGRANGIAN POINT L1

ACE (ADVANCED COMPOSITION EXPLORER)

Studying the Sun. Has enough fuel to last until 2024.

DSCOVR (DEEP SPACE CLIMATE OBSERVATORY)

Studying the Sun and climatic changes on Earth.

WIND

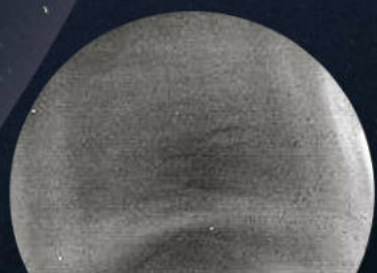
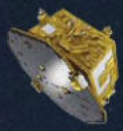
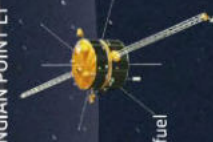
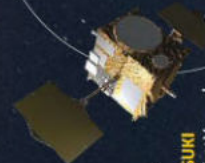
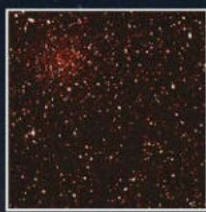
Studying the solar wind. Has enough fuel to last another 53 years.

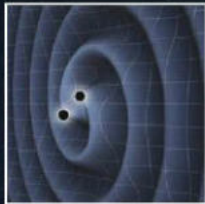
SOHO (SOLAR AND HELIOSPHERIC OBSERVATORY)

Studying the Sun's outer layers as well as the solar wind.

LISA PATHFINDER

Testing out technology for a gravitational wave observatory.



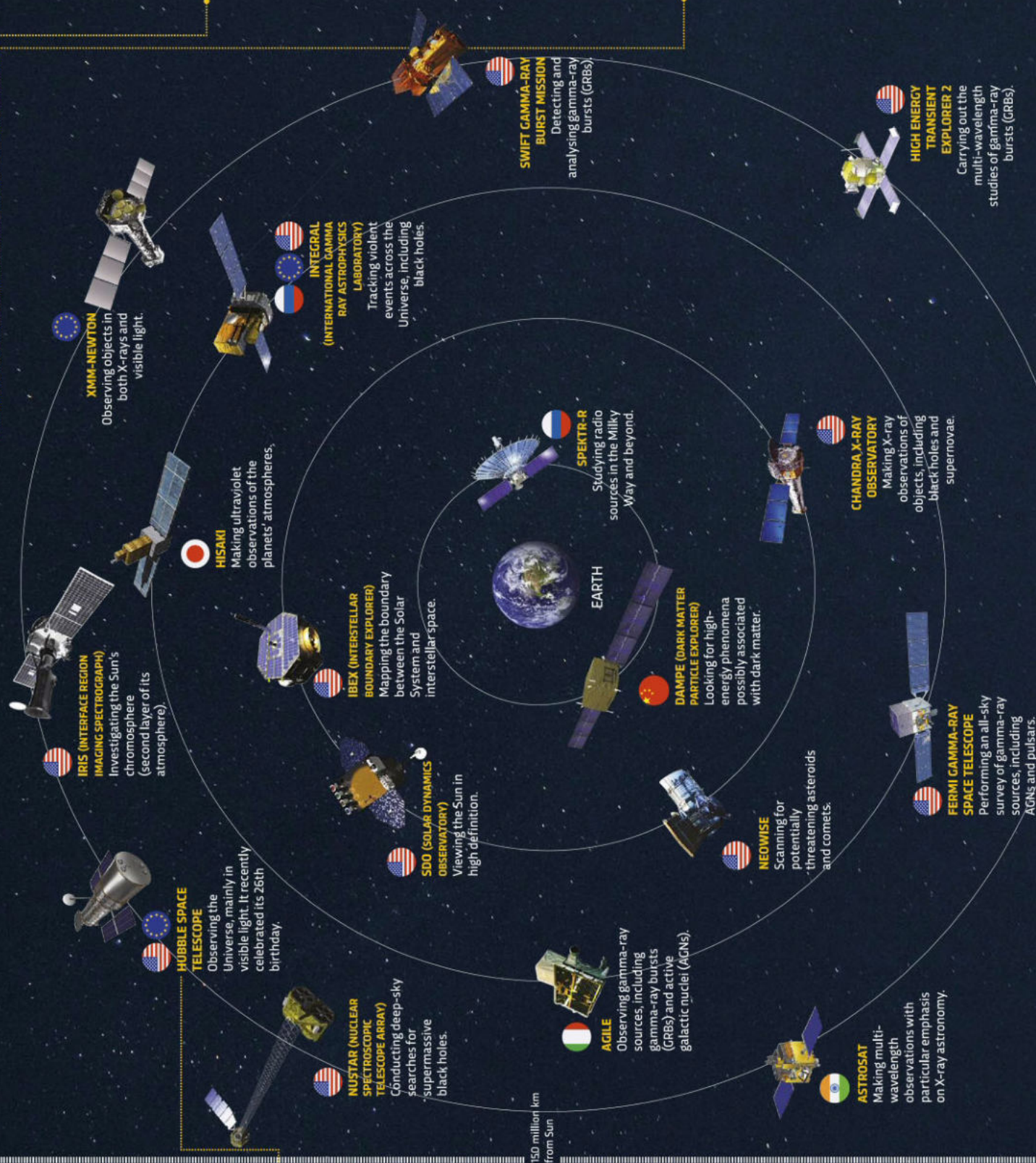


LISA

PATHFINDER
Gravitational waves are the buzzwords in astronomy and physics right now. They are tiny ripples in the fabric of space itself. Predicted by Einstein in 1915, they come from violent events such as the collision of black holes. A proposed space-based mission called LISA would be a significant boost to our ability to detect these tiny disruptions, and LISA Pathfinder has shown that such a mission is feasible.

SOLAR AND HELIOSPHERIC OBSERVATORY

The SOHO mission revolutionised our understanding of the Sun. It was the first time we'd had our closest star under near-constant surveillance. As well as providing valuable data on the Sun's magnetic activity, it also inadvertently discovered 3,000 comets as they buzzed past.



HUBBLE SPACE TELESCOPE

When the Hubble Space Telescope entered service in 1990, its images were found to be slightly blurry – traced back to a flaw in its primary mirror. A complex service mission in 1993 fixed the issue and, since then, the telescope has been beaming back spectacular images of the cosmos. Perhaps its most iconic snapshot is the Hubble Deep Field, in which it focused on a tiny, nearly empty patch of space for 10 days. The resulting image showed that this apparent void was actually chock-full of distant and diverse galaxies, providing a new glimpse into the early Universe. The telescope's contribution to astronomy has been far-reaching, enabling scientists to pin down the age of the Universe, discover dark energy, and witness the birth of planets and stars.

HAYABUSA 2

Its predecessor was the first time we'd returned a sample of an asteroid to Earth. However, that mission was plagued with problems, so hopefully this time things will run more smoothly and return more material for scientists to study.



DAWN

Dawn has gone down in history as the first probe to enter into orbit around two completely separate bodies in the same mission. Its innovative ion propulsion technology was key to getting in and out of the gravitational field of these two protoplanets. The white spots it has detected on Ceres continue to enthrall astronomers, dangling the possibility that they might be areas of water ice. Such missions are crucial precursors to any future attempts to mine asteroids for their wealth of resources.



DAWN
Exploring the asteroid Vesta and dwarf planet Ceres.

EXOMARS TRACE GAS ORBITER
Will investigate methane in the Martian atmosphere. Due to arrive in October 2016.

MARS ATMOSPHERE AND VOLATILE EVOLUTION MISSION (MAVEN)
To discover how Mars lost its atmosphere and liquid water.

CURIOSITY
Assessing suitability of Martian environment for microbial life.

MARS EXPRESS
Performing comprehensive analysis of the Martian environment.

MRO (MARS RECONNAISSANCE ORBITER)
Monitoring Martian climate and mapping future landing sites.

2001 MARS ODYSSEY
Detecting evidence of past or present water on Mars.

OPPORTUNITY
Searching Mars for signs of past water and amenable conditions for life.

MARS ORBITER MISSION
Demonstrating technology for future Indian Martian mission.

HAYABUSA 2
Will survey an asteroid and return a sample to Earth. Due to arrive at asteroid 162173 Ryugu in July 2018.

LRO (LUNAR RECONNAISSANCE ORBITER)
Making detailed lunar maps for future manned and robotic exploration.

ARTEMIS PI/P2
Studying the interaction of the solar wind with the Moon.

CHANGE 3
Exploring the Moon's geology from its location on Mare Imbrium.

GAIA
Accurately cataloguing the positions of a billion stars.

LAGRANGIAN POINT L2

CHANGE 3

This rover, nicknamed Jade Rabbit, touched down on the Moon in December 2013, making China only the third country to land on the lunar surface. It was the first soft landing on the Moon since 1976. Three years later, it was announced that the rover had found a new type of lunar rock. High quality images – including of the Earth and the Pinwheel Galaxy – were taken.

CURIOSITY

As planetary missions go, few are as daring as Curiosity. Previous Martian rovers had been lowered onto the Martian surface inside inflatable balls, which slowly deflated to leave the machine to roll out onto Mars. But Curiosity was gently lowered onto the surface via an intricate 'sky crane'. Curiosity has now experienced two full cycles of the Martian seasons and is on its way to Mount Sharp.





NEW HORIZONS

When the mission set off in early 2006, the world it was heading to was still a planet. Later that year, however, Pluto was downgraded to dwarf planet status by the International Astronomical Union. Yet that couldn't stop the worldwide excitement as New Horizons finally ended its nine-year journey to the Kuiper Belt last year. For the first time, we had crisp, close-up images of this world, and they didn't disappoint. Mission scientists were left baffled by how smooth and crater-free Pluto's surface is. That suggests this little world must have some kind of geological activity that constantly re-sculpts its surface. We also got closer views of Pluto's five moons: Charon, Nix, Hydra, Kerberos and Styx.

779 million km
from Sun

1.43 billion km
from Sun

2.87 billion km
from Sun

4.50 billion km
from Sun

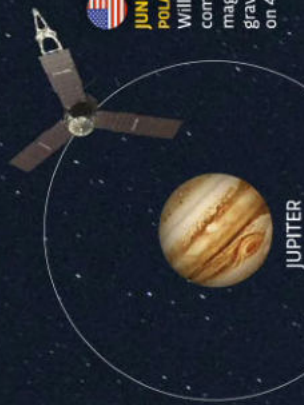
5.91 billion km
from Sun



ROSETTA
Mapping the comet 67P/Churyumov-Gerasimenko.

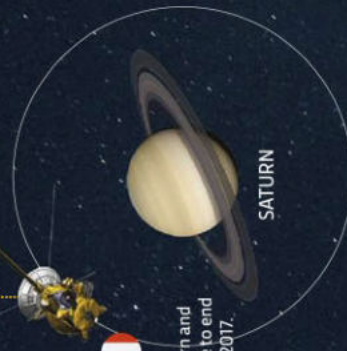
PHILAE
Made the first ever landing on a comet.

COMET 67P/CHURYUMOV-GERASIMENKO



JUNO (JUPITER NEAR-POLAR ORBITER)
Will explore Jupiter's composition, magnetism and gravity. Due to arrive on 4 July 2016.

JUPITER



CASSINI
Studying Saturn and its moons. Due to end in September 2017.

SATURN



URANUS



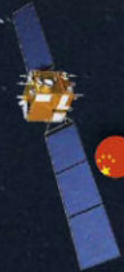
NEPTUNE



PLUTO



NEW HORIZONS
Explored Pluto and its moons. Now studying the Kuiper Belt.



CHANG'E 2
Exploring the Moon and asteroids. Currently 100 million kilometres from Earth.

CASSINI

Cassini ranks as one of the most successful interplanetary missions in history. It arrived at Saturn in 2004 after a seven-year voyage and has been beaming back gorgeous images and valuable data ever since. Its most famous image is probably the one showing a solar eclipse, with Earth appearing as a tiny dot. The Huygens lander piggybacked along, before touching down on the surface of Saturn's largest moon, Titan, in 2005. It's the only occasion we've landed in the outer Solar System.



VOYAGER 1

In August 2012, it was confirmed that Voyager 1 had departed the Solar System. But it still has a long way to go before it reaches the Oort Cloud – technically still part of the Solar System. Instead, it has left the magnetic influence of the Sun, as the solar wind is lost in the winds of other nearby stars.



VOYAGER 2
Explored Jupiter, Saturn, Uranus and Neptune. Now close to the edge of the Solar System. 16.5 billion kilometres from Earth.



VOYAGER 1
Explored Jupiter, Saturn and its largest moon Titan. Has now left the Solar System and is over 20 billion kilometres from Earth.



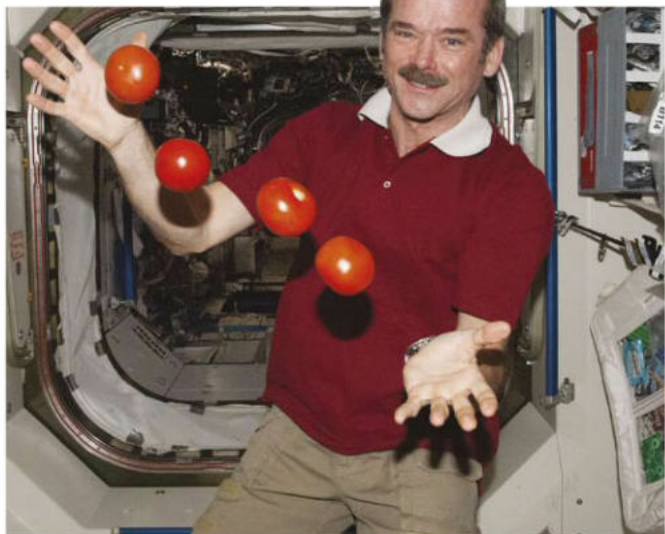
Why haven't spacesuits changed much?

Spacesuits have actually changed enormously. The earliest spacesuits were essentially just airtight versions of the flight suits that pilots wore. In 1965 cosmonaut Alexei Leonov almost became stranded in space during the first spacewalk, when his spacesuit ballooned out so much from its internal pressure that he couldn't move or operate the airlock door. The A7L suits developed for the Apollo missions used constant-volume joints to avoid this problem and added a self-contained air recycling unit and 100m of piping to pump cooling water around the suit. The suits were custom tailored and each astronaut needed three

Aerospace engineer Dava Newman developed this BioSuit for Mars missions; it has a tight, elastic structure that counteracts lower pressures



suits (for training, flight and a spare) costing around \$500,000 each. The EMU and Russian Orlan suits, currently used on the International Space Station, are modular to keep costs down. Plus, because they are only used in microgravity, they can be much heavier. These suits have a rigid upper torso, which offers better protection and comfort. For future missions to Mars, NASA is developing the Z-series suits that have rigid joints with titanium bearings to allow the greatest flexibility. These are the first spacesuits that allow the wearer to touch their toes, and they also have a built-in airlock. **W**



Is it harder to think straight in space?

Space travel is definitely disorienting. Without the effects of Earth-like gravity on the sensory system in the inner ear, your brain no longer has any clear idea about what is up and what is down. This can affect astronauts' ability to sense distances and rotate objects in their mind's eye and it can provoke some weird perceptual experiences such as the sudden sense that everything around them has been turned upside down, or the converse, that they themselves have been flipped. Add to that the fatigue, the constant hum of equipment, the loneliness and claustrophobia, and perhaps it's no wonder that experts talk about astronauts suffering from 'space stupids' or 'space fog'. **q**

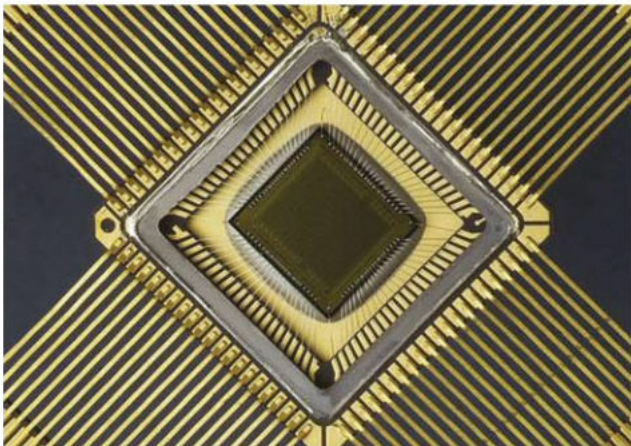
Love our Q&A pages? Follow our Twitter feed @sciencefocusQA



How are computers protected from radiation in space?

Space can be a dangerous place for electronics because solar flares or galactic cosmic rays can cause power resets or system failures. Electronics are protected from these dangers using several clever methods. Shielding helps stop the harmful rays reaching the delicate chips. Plus, redundant components are used, so that if one is damaged, another can take over. Special radiation-hardened (RadHard) electronics are made from Silicon-on-Insulator or Silicon-on-Sapphire instead of the normal semiconductor wafers to make them thousands of times stronger against radiation. Reconfigurable electronics are utilised, which allow circuits to be adjusted remotely in order to make them work again. **PB**

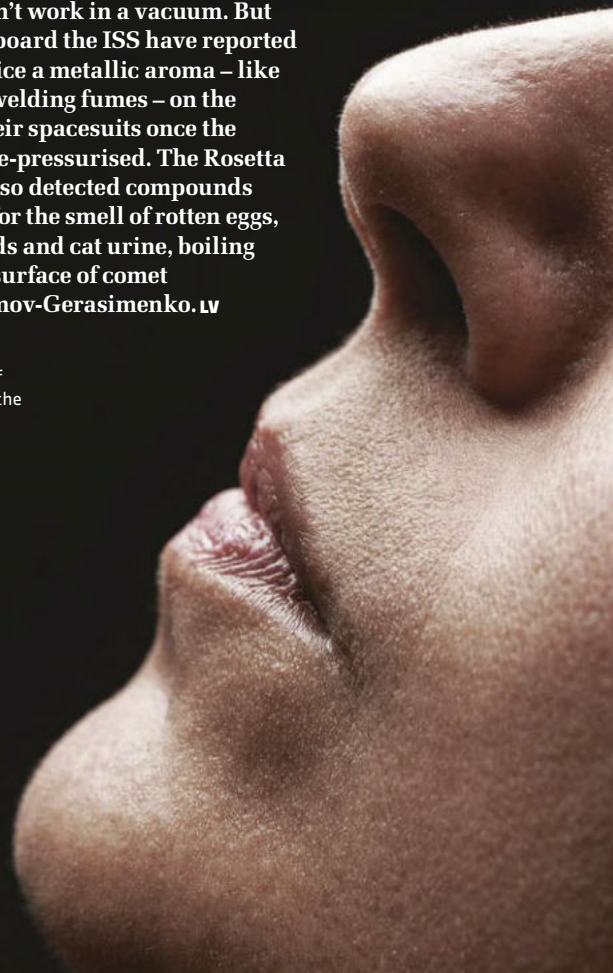
One of BAE's radiation-hardened chips



What does space smell like?

We can't smell space directly, because our noses don't work in a vacuum. But astronauts aboard the ISS have reported that they notice a metallic aroma – like the smell of welding fumes – on the surface of their spacesuits once the airlock has re-pressurised. The Rosetta spacecraft also detected compounds responsible for the smell of rotten eggs, bitter almonds and cat urine, boiling off from the surface of comet 67P/Churyumov-Gerasimenko. **lv**

"I love the smell of welding fumes in the morning"





ASK AN

Shannon Walker is an American scientist and NASA astronaut who blasted off from the Baikonur Cosmodrome in June 2010 to spend five months aboard the International Space Station

How do you decide which way is up on the ISS?

Directions tend to lose their meaning in space, so we don't really need a formal up and down. But we orient ourselves according to the way the modules are presented to us in training. On the ground, we have simulators of all the International Space Station modules, and these have a definite orientation. One plane of the modules has lights attached, so you want the lights on the ceiling, just like they are at home. And then everything else on the ISS is designed around that, so that when you're having meals or floating around, your heads are all pointing towards the lights.



How quickly do you get used to microgravity?

It's strange to feel weightless, but it's interesting how quickly it becomes a natural state – it only takes a few days to get used to floating. What takes longer is figuring out that you have to push off to get anywhere, and knowing how hard you need to push. Some people feel motion sick when they first arrive, but that tends to go after a day or two.

What is a 'cosmic fairy', and have you seen one?

Yes, almost everyone on the ISS experiences these little flashes of light when they close their eyes. It's kind of like when you see



a shooting star streaking across the sky, but inside your eye. It's pretty neat. The lights are caused by cosmic rays interacting with your retinas. On Earth, we're protected from this radiation by the planet's magnetic field. We don't have a lot of data on what effect these rays are having on astronauts in the long term, but that's something we're currently studying.

Do astronauts really love prawn cocktail?

We definitely eat a lot of prawn cocktail in space, and it's pretty tasty. I'm not sure why this particular food gets so much attention, though – the prawns are a little rubbery! I think astronauts are mostly looking for foods with a strong flavour, as the meals in space don't have as much variety as on the ground. When I was there I really liked the Japanese and Indian curries. And I also had a great barbecue beef.

Some people say that they lose their sense of taste in space. You don't have gravity pulling all the fluids down in your body, so they travel towards your head and can cause congestion, affecting your sense of smell and taste. But it depends on the person – my taste buds seemed pretty much the same.



ASTRONAUT

"We definitely eat a lot of prawn cocktail in space, and it's pretty tasty. I'm not sure why this particular food gets so much attention, though – the prawns are a little rubbery!"



What advice would you give to Tim Peake about adjusting back to life on Earth?

Take it slowly. You'll have aches and pains, and your inner ear will be trying to readjust, so you might feel dizzy and unable to walk in a straight line. But you'll soon feel like your old self again. Spend time with your family – they've been on this adventure with you, but they haven't been in your presence for a long time. Savour the moments you had in space.



How does the ISS loo work?

Fans provide a gentle airflow and suction. There's a hose with a funnel for urine, which is recycled into drinking water, and a separate tank that you sit over for your solid waste.



What happens if there's a fire?

This is something we train for a lot. First, the Space Station tries to take care of the problem itself. We've got smoke detectors all over the place, so if an experiment goes haywire and starts creating smoke, the ISS will automatically know where the issue is and start turning off electricity in that area. You may have lights and fans shutting down – you don't want to keep blowing oxygen across the fire.

The crew is trained to gather in a central location and make sure everybody's safe. If we can see the fire, and it's simple and well-contained, we can use the onboard fire extinguishers. Otherwise, we shut down or depressurise the module where the fire is, and it'll eventually go out. There's never been a fire on the ISS, but they did have a couple of incidents on the Mir space station.



What's the least glamorous task on the ISS?

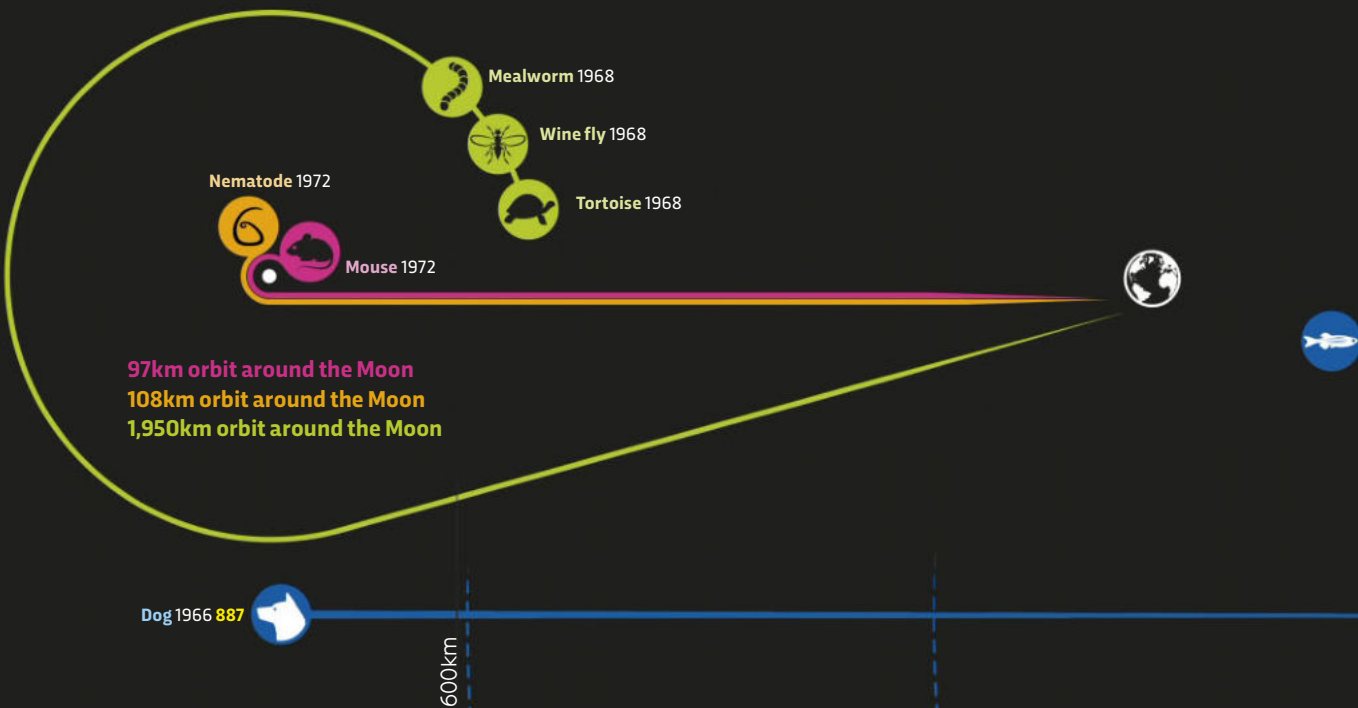
Most of our job isn't glamorous at all! We still have to clean – we do housework and vacuuming, and somebody's got to pack up the solid waste from the toilet and get it ready for the cargo ships to take away. Being an astronaut definitely has its perks, but it's not all Hollywood.

How do astronauts keep clean?

There's no shower on board, so we use wipes or a soapy towel. Washing your hair is a little trickier. We use no-rinse shampoo, but it still needs to be used with water from a drink bag. You have to be careful not to leave water floating around – you don't want to be shorting out electrical systems.



More animals than people have visited space. Usually, they are sent to study the effect of space travel on different elements of their physiology, such as their DNA, reproductive systems or inner ears.



Which animals have visited space?

First animal in space – fruit fly

Fruit flies were the first animals ever sent to space. In 1947, they were launched to an altitude of 109km in the nose cone of a V2 rocket captured from the Nazis. The capsule ejected and returned the insects safely back to Earth by parachute.

First animal in Earth orbit – dog

Laika was the Russian dog that was the first animal sent to Earth orbit – and the first to die there in 1957. But the altitude record for dogs belongs to Veterok and Ugolyok who flew in Kosmos 110 in 1966.

First monkey in space – rhesus macaque

The first monkey in space was Albert II, a rhesus macaque. He was killed on impact when his V2 rocket's parachute failed. The altitude record for (non-human) primates was set in 1959 by rhesus and squirrel monkeys, called Able and Baker.

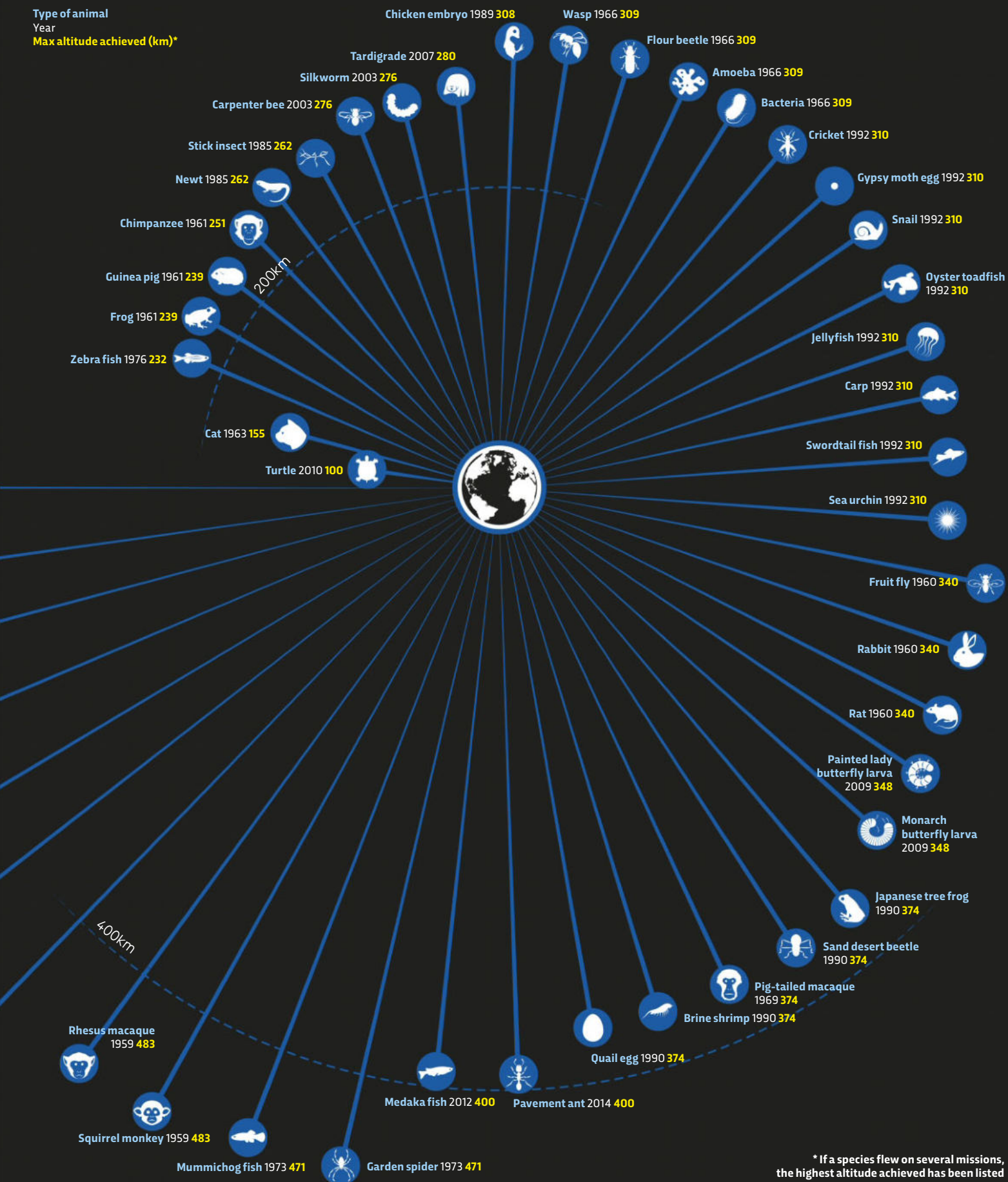
First animal to orbit the Moon – tortoise

In 1968, three months before Apollo 8, two Russian tortoises won the race to be the first animals to travel around the Moon, along with some flies, worms and bacteria. They flew aboard the Zond 5 spacecraft and returned safely to Earth after a seven-day voyage.

First animal to give birth in space – cockroach

In 2007, a cockroach called Nadezhda ('Hope', in Russian) became the first Earth creature to give birth in space. Nadezhda conceived and bore 33 young in microgravity, while travelling 258km above Earth in the FOTON-M3 spacecraft. The space cockroaches matured slightly faster but otherwise seemed normal.

Type of animal
Year
Max altitude achieved (km)*



* If a species flew on several missions, the highest altitude achieved has been listed

Can we reproduce in space?

We don't know yet. Rats that flew in space for part of their gestation were later born on Earth without the ability to right themselves, and other studies have shown that gravity is important for proper foetal development. Future colony ships may need to include centrifuge cabins to provide artificial gravity for any pregnant crew. **LV**

No babies have been conceived in space... yet



My Very Easy
Method Just
Speeds Up
Naming... oh...

Could Pluto become a planet again?

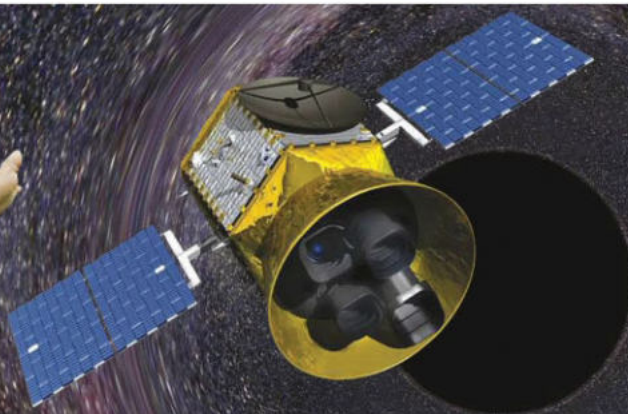
When it was discovered in 1930, Pluto was hailed as the ninth planet in the Solar System. But in 2006, it was controversially downgraded to mere 'dwarf planet' status by the International Astronomical Union, on

the grounds that it's too small to clear its own path around the Sun. Despite repeated calls, Pluto has no chance of becoming a planet again without the IAU dropping its orbit-clearing criterion. **RM**

How close to a black hole could a space probe get?

Anything that passes beyond the 'event horizon' of a black hole is lost forever. However, a space probe would be destroyed long before reaching this point. This is because the black hole pulls much harder on the front of the space probe than on the back, stretching it and tearing it apart in a

process called 'spaghettification'. How close your space probe can get to the black hole before being destroyed depends on the black hole's size (or mass) and the strength of your probe's construction. Counterintuitively though, a smaller black hole is much more dangerous than a larger one! **AG**



Why is there poo on the Moon?

The Apollo landers were designed to lift off from the lunar surface at a particular weight. Since the Apollo astronauts were charged with bringing large amounts of Moon rock back home, the weight of those samples was offset by leaving behind unwanted items. This discarded junk included, among other things, two golf balls, 12 cameras, 12 pairs of boots, a gold-plated telescope, and a total of 96 bags of 'human waste' – urine, faeces and vomit! Although not the best example of green thinking, this detritus will have had no permanent effect on the lunar environment. Any microorganisms present in the human waste could not have grown under the harsh conditions of the lunar surface. It is possible, however, that some could have survived for a time as dormant, inactive spores. So, after 50 years on the lunar surface the human waste, which is now probably just bags of dust, may contain important information on the survival of microorganisms in space. Astrobiologists would like to see if any of those microorganisms have undergone any genetic mutations due to the harsh lunar environment, or have indeed survived in a dormant state. They hope one day that private companies may eventually return this human waste for study! **AG**

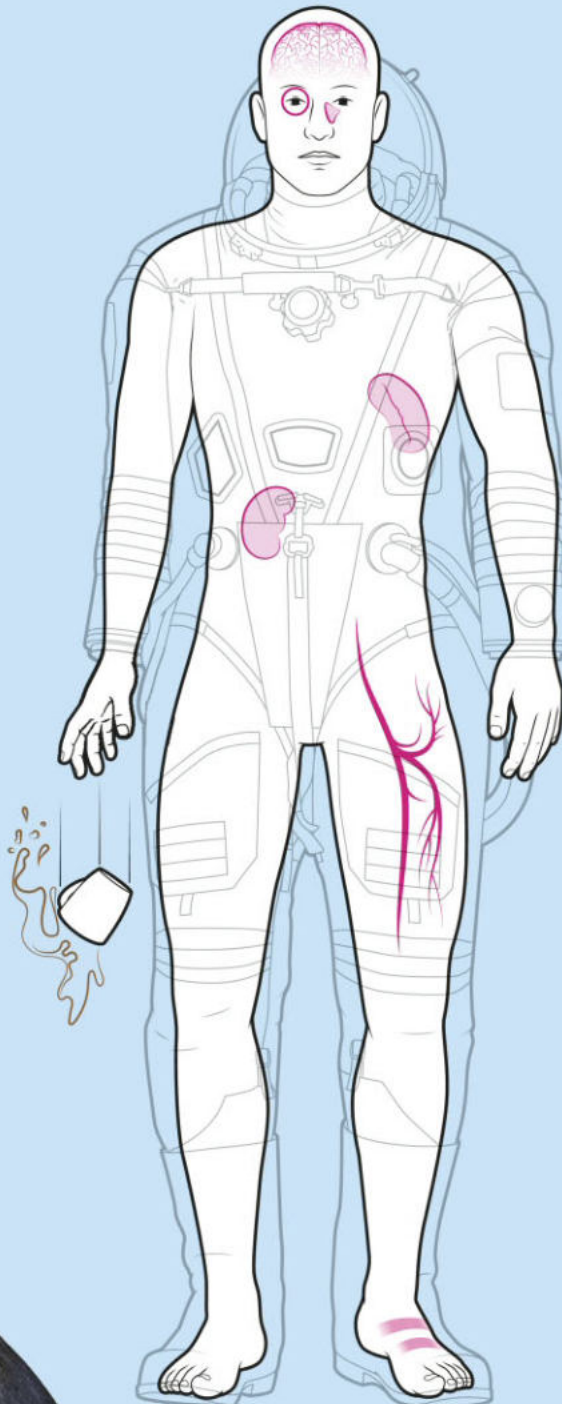
PHOTOS: GETTY X2, NASA, ISTOCK ILLUSTRATION: CHRIS PHILPOT



Who knows what could have become of the poo left on the Moon?

What happens to the body in space?

On a five-month trip to the ISS you can expect to lose 12 per cent of your bone density and 40 per cent of your muscle mass – even with daily sessions on the treadmill. This is the equivalent of ageing from 20 to 60 in a few months. Without gravity pulling it down, the fluid in your body redistributes, and your heart grows weaker. But there are some more subtle and unexpected changes too. **LV**



Brain

Mice exposed to the radiation levels typical of a journey to Mars showed more beta-amyloid proteins in their brains. This means that long space journeys could increase the chance of developing Alzheimer's disease.

Eyes

Fluid redistribution increases the pressure on the eyeball, slightly crushing the optic nerve, which can lead to visual problems later on. Increased radiation levels also raise the chance of developing cataracts.

Sinuses

Increased fluid in the head causes nasal congestion, bulging neck veins and a puffy face, which combine to feel like a constant head cold.

Mouth

Astronauts report that food tastes more bland in space, so many prefer to eat spicy food. In microgravity, gases in the stomach do not separate from liquids, so astronauts tend to have unpleasant 'wet burps'.

Coordination

Astronauts get used to things floating and their reflexes recalibrate to allow them to catch moving objects in microgravity. When they return to Earth, they are initially more clumsy and drop things.

Kidneys

Lost bone mass ends up as calcium in the bloodstream and this can precipitate into painful kidney stones.

Immune system

The T-cells in your immune system don't reproduce as well in space, making astronauts more prone to bacterial infections.

Blood

For the first few days in space your body destroys any newly produced red blood cells. This stops eventually, but your red blood cell count remains lower until you return to Earth.

Feet


The hard skin on the soles of your feet moults off because it's not in constant contact with the ground any more. But the tops of your feet become raw and sensitive from rubbing against the foot straps astronauts use to secure themselves in space.

Feed your mind



Micronutrients with iron, zinc & iodine,
which contribute to normal **cognitive function**

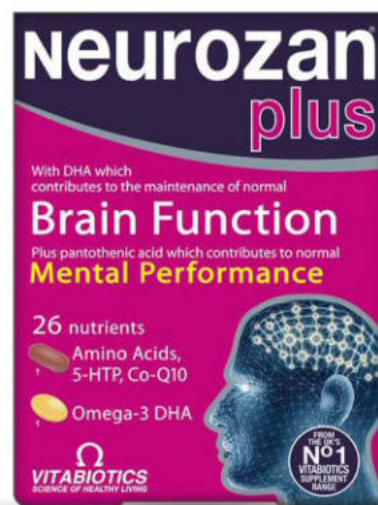
Neurozan® is an advanced, comprehensive formula to help safeguard your daily intake of essential vitamins and minerals. Including iron, zinc and iodine which support normal **cognitive function** and pantothenic acid which supports normal **mental performance**.

Neurozan® Plus dual pack provides even greater nutritional support with high purity Omega-3 DHA from Norway.  DHA helps to maintain normal **brain function†**.

So if you're looking for a supplement that's different, keep **Neurozan®** in mind.



ORIGINAL



DUAL PACK WITH DHA

Neurozan® tablets

From  Boots, Waitrose,
Holland & Barrett, supermarkets,
chemists, health stores & www.neurozan.com

†A beneficial effect is obtained with a daily intake of 250mg DHA.

*Nielsen GB ScanTrack Total Coverage Value Sales 52 w/e 25th April 2015.





ROBIN INCE ON... **MUSIC FESTIVALS**

"DOES SCIENCE SUGGEST THAT THE EXPERIENCE OF SUMMER FESTIVALS IS GOOD FOR OUR WELL-BEING?"



he Klingon lunged for me, but in doing so, his spiny forehead came loose and fell to the ground.

Revealing his human head reality, ashamed, he ran back into the pit of heckling and fury. This was my abiding memory of Glastonbury 1998.

The music festival has gone from outsider cultural activity, apparently populated by naked, drug-filled pagans and facially tattooed anarchists, to the sort of events contentedly critiqued by the *Daily Mail*, with a pictorial spread on the best wellingtons worn by the attending supermodels.

Alan Moore, counter-cultural icon for four decades, went to a contemporary festival in 2013. He was flabbergasted by what he saw. What were once ramshackle and fecund fields of rebellious ideas now had swanky salmon burger retailers and corporate sponsorship. In his words, "it seemed I was the only one who wanted to spoil everyone's fun".

So what purpose do festivals serve now, bar from being an excuse for a bacchanalian weekend?

Maybe it's all about the cortisol. According to a recent study at Imperial College London, there is evidence that "attending a cultural event can have an impact on endocrine activity and downregulate stress". Saliva tests taken before a gig and during the interval showed that stress hormones had markedly reduced. At this year's festivals, I think I'll bring along my saliva home-testing equipment to find out which bands are most likely to reduce my stress levels. My money is on Public Service Broadcasting, with *Savages* a close second. I might see if I can get them on prescription.

An increasing number of academics are now scrutinising festivals, which sounds like a great alibi for calling a good time hard work.

Some postulate that as people find their senses increasingly stimulated by virtual worlds, real-world



events have to be more spectacular. Today's music festivals offer spectacle in abundance, which might go some way to explaining their popularity. The collision of sounds from nine different bands at once leaves a lasting impression, as does the bevy of fire jugglers spinning past you, dizzy from perry and paraffin.

Then there's that feeling of togetherness. It's in shared corners of fields that the unity lacking in everyday urban society can be rekindled. In 2011, researchers at the University of Queensland interviewed festival-goers aged between 18 and 29 to find out how music festivals affected their well-being. "Participants reported feeling more positive about themselves, others, and life in general as a result of attending a music festival," wrote the researchers. "Sharing the experience with others provides a sense of belonging and social integration, which can often continue beyond the event itself."

Being placed in a field, especially one with a liquor licence and a free jazz bongo drum parade, can lower the resistance to social interaction. The mind can be altered without taking anything mind-altering. Philip K Dick worried that mass culture was eager to disturb the senses, but not the mind; a gregariously curated festival will disturb both.

While the UK may now be littered with festivals, perhaps what is missing is something akin to the USA's Burning Man festival, which takes place in the Nevada desert. Here is a public arts festival where only coffee and ice is for sale – everything else is down to barter and altruism. According to neuroscientist Molly Crockett, the removal of money allows kindness and generosity to flourish – indeed, studies show that even thinking about money makes people less helpful towards others. As Crockett states, "Burning Man is, of

course, radically different from the real world." I think we need a few more radical alternatives to the real world, even if it is only for a few days. **f**

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage*.

NEXT ISSUE: ANIMAL COMPANIONSHIP

WHERE ARE ALL THE **CLONES?**

*It's 20 years since scientists in Edinburgh
cloned Dolly the sheep. Commentators
at the time promised us a world overrun
by cloned animals and humans.*

So where are they?

WORDS: HENRY NICHOLLS



Embryologist Bill Ritchie knew that Dolly the sheep would be big news. But looking back to the days after the press got wind of the cloned

sheep, he is still amazed by the sensation she caused. "By the Monday morning, the place was just full of trucks with dishes sending the news around the world," says Ritchie, then at the Roslin Institute in Edinburgh and one of the researchers behind the creation of Dolly. "All hell had broken loose."

One reporter imagined that Dolly might herald "a scientific explosion comparable to the atom bomb or the Moon rocket or DNA itself". There were accusations that the scientists were 'playing God'. Some envisaged herds of cloned sheep, consisting of thousands of identical sisters. One commentator even raised the alarming prospect that "any decent college or graduate school student could potentially clone a human being". Others were more positive, seeing cloning as a lifeline for endangered species.

Given the excitement and such wild predictions of a future overrun by clones, it's reasonable to ask what happened. Where are all the clones now? What worked and what didn't? Who's still cloning and why? Twenty years after Dolly, what is her legacy?

"Everyone thought it was going to be so easy," says Ritchie. But it isn't. In the case of Dolly, Ritchie succeeded in creating 277 cloned sheep cells. Of these, only 29 began to divide normally and were implanted into surrogate ewes. There was just one pregnancy that reached term. "It's not a particularly efficient technique," he explains. "I sometimes wonder how it works at all."

But have we learned anything to help us improve this efficiency? "Not a lot," says Ritchie. "It's still a very inefficient process." This fact helps explain why so many of the applications envisaged for cloning have not taken off. ●

CLONING

Take agriculture, for instance. There would be huge interest in copying the most prized individuals in a herd, simultaneously improving the quality and consistency of the animals. But the low success rate of cloning, coupled with concerns over the safety of consuming cloned products, means that only the boldest players dare to dabble. In China, the world's largest animal-cloning factory will soon begin operations in the city of Tianjin. BoyaLife's aim is to produce 100,000 high-quality cow embryos with a view to feeding China's growing appetite for beef, eventually scaling up to one million animals a year.

The inefficiencies involved also mean that cloning of valuable animals remains a relatively niche activity that's only accessible to the super-rich. In Idaho in the US, for instance, businessman and mule-racing enthusiast Donald Jacklin ploughed some of his wealth into a project to clone a mule. Cloning has also been used to create breeding replicas of castrated racehorses. It's not cheap, but given the astronomical fees that a valuable stud can command there might be a financial incentive. But it remains a niche activity.

EXTRA LIVES

Another application of cloning is the promise of creating a clone of a favourite pet after it has passed away. But the idea makes little sense, business or otherwise. "Why clone a pet?" asks Ritchie. "It might look the same as the last animal you had but is not going to have the same personality." But this didn't stop British couple Richard Remde and Laura Jacques flying to South Korea at the end of last year to be present at the birth of two puppies cloned from their recently deceased pet boxer Dylan. The Soom Biotech Research Foundation relieved Remde and Jacques of the princely sum of £60,000 "to prolong the companionship with your dog by bringing back the memories that you have with your friend".

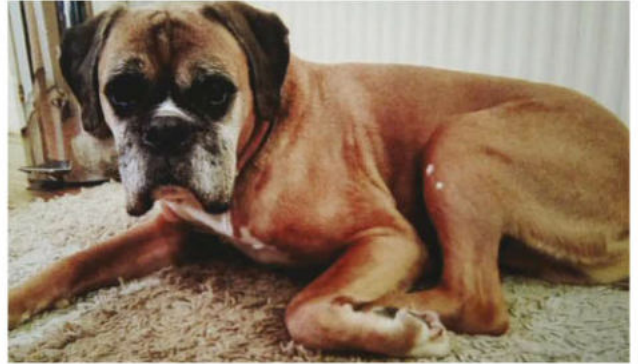
The promise of cloning to save threatened species has not been realised either for the simple



ABOVE: Dog-loving UK couple Richard Remde and Laura Jacques, splashed out £60,000 to create clones of their boxer dog Dylan

RIGHT: Dylan died from a seizure at the age of eight

BELOW: These two boxer puppies, born in December 2015, were cloned from Dylan



PHOTOS: THE GUARDIAN X3, GETTY X2

TIMELINE: ANIMALS WE'VE CLONED

1894



German biologist Hans Driesch takes a two-cell sea urchin from

the Bay of Naples and shakes it in beaker of water. The cells part, giving rise to two, independent but identical, sea urchins.

1902



Hans Spemann, another German scientist,

uses a fine hair from his baby son to split a salamander embryo in two. The result: two amphibians for the price of one.

1952



In the US, Robert Briggs and Thomas King perform a successful

nuclear transfer, by moving a nucleus from an embryonic frog cell into an egg cell whose own nucleus had been removed.

1962



Instead of using nuclei from frog embryos, Oxford biologist John Gurdon

takes them from adults, demonstrating that a differentiated nucleus still has the power to build an entire animal.

1963



Chinese embryologist Tong Dizhou applies the same technique

to fish, though his work, originally published in his native Chinese, does not receive much attention beyond China.

THE LIFE OF DOLLY THE SHEEP

The udder cell that provided the nucleus that gave rise to Dolly came from a six-year-old white Finn Dorset sheep.

The nucleus from the udder cell was injected into an egg cell from a Scottish Blackface ewe.

The cloned lamb began life with the codename 6LL3.

In recognition of her udder origins, 6LL3 became known as Dolly, after the big-busted singer Dolly Parton.

When Dolly was born on 5 July 1996, she weighed in at a fairly hefty 6.6kg.

Dolly had six healthy lambs in her lifetime. Her first, Bonnie, was born in the spring of 1998.

In 2001, Dolly was treated for arthritis. The Roslin Institute denied she was ageing prematurely.

Dolly was put to sleep on Valentine's Day 2003, following the discovery of tumours growing in her chest.

Dolly was stuffed and went on display at the National Museum of Scotland in Edinburgh.



ABOVE: Dolly with Dr Ian Wilmut, one of the scientists who created her

reason that there is, by definition, a serious shortage of females to act as surrogates. There are isolated success stories – the European mouflon, a type of wild sheep found on Corsica and Sardinia, was successfully cloned in 2001 – but they are all species with a closely related domestic species capable of receiving the embryo.

For the scientists involved in the creation of Dolly, all these applications of cloning (agriculture, pedigree, pets, conservation) were never a priority, says Miguel Garcia-Sancho, a historian of science at the University of Edinburgh. "They didn't regard cloning as an end in itself." It was just one of the

"A cloned pet might look the same as the last animal you had, but won't have the same personality"



1996



The cloning of Dolly the Sheep builds on Gurdon's method, showing that the nucleus from a differentiated cell retains the ability to make an entire animal

from scratch, even in mammals. A total of 277 cloned sheep cells were created, with 29 of them developing into embryos. Dolly was the only one who continued developing after implantation into a surrogate ewe.

2001



Researchers at Texas A&M University create the first cloned

pet, using a cell from a brown-and-white tabby cat called Rainbow to make 'CC' (aka 'Copy Cat' and 'Carbon Copy').

2001



Scientists at Advanced Cell Technology in the US are the first to clone

an endangered species. Noah the gaur, a species of wild ox native to Asia, dies from dysentery after two days.

2005



Controversial South Korean scientist Hwang Woo-Suk

uses the ear cell from an Afghan hound to make Snuppy, the world's first cloned dog. A Labrador acts as surrogate mother.

steps, albeit a crucial one, on the way to producing genetically modified animals, he says.

By the time news about Dolly broke in February 1997, the researchers at the Roslin Institute were already well on the way to producing several more cloned sheep but with one crucial difference. They were not exact copies, as Dolly had been. The nucleus (the section of a cell that contains most of the genetic material) used to create each sheep had been modified to contain a human blood-clotting protein, factor IX. The idea was that these sheep would have this protein present in their milk. The protein could then be harvested and used to treat patients with haemophilia. The basic reasoning was sound and the sheep did have the protein in their milk, though not in sufficient quantities to be commercially viable.

CLONES TO THE RESCUE

In spite of this setback, cloning is an indispensable step in the creation of genetically modified animals that can be vital for scientific research. One of the most valuable applications has been to improve on existing mouse models of human disease.

"A mouse is not a human," says Angelika Schnieke, a key player in the Dolly project and now chair of livestock biotechnology at the Technische Universität München in Germany. "A pig is not a human either but its physiology is a lot closer." In

the last few years, cloning has been used to create pig models of cystic fibrosis, bowel cancer, diabetes and cardiovascular disease. These are being used to test new medications, imaging technologies and treatment options.

In addition, cloning has brought us closer to a world in which pig organs could be routinely used in transplantation. By making modifications to embryonic pig cells and introducing a smattering of human genes, researchers have been able to clone pigs with organs that are less likely to be rejected by the human immune system.

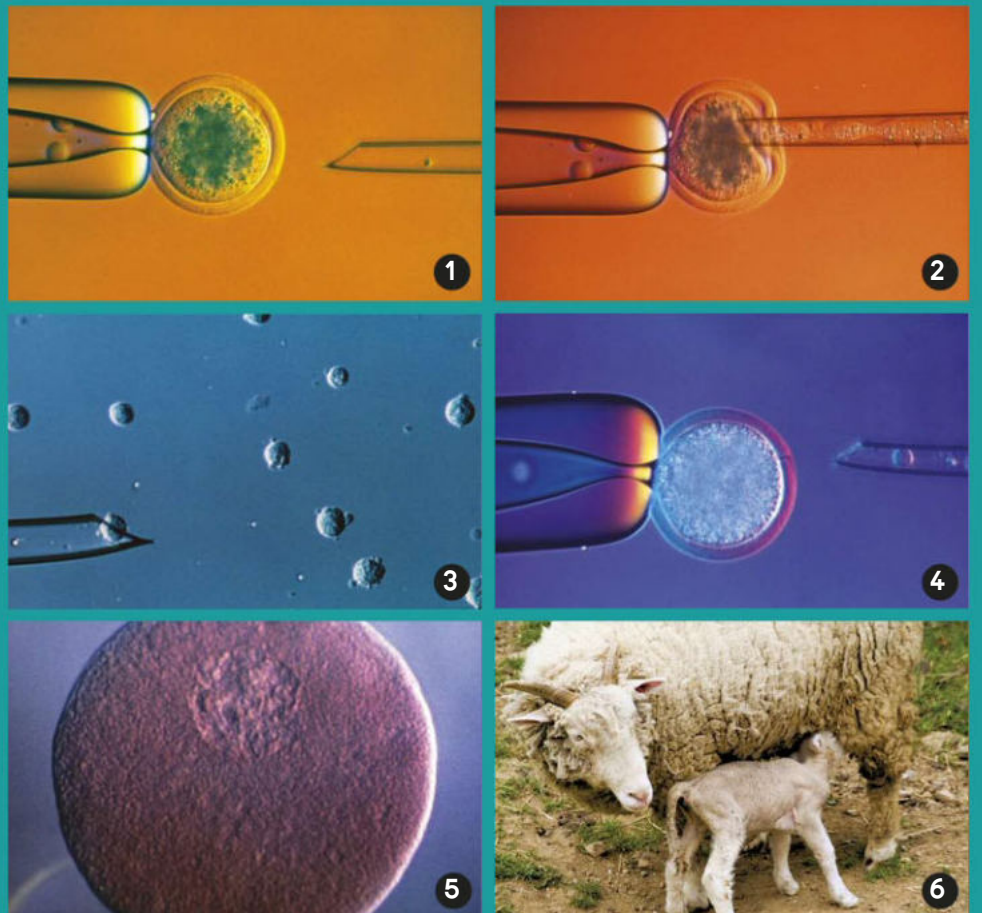
With cloning, it's also possible to think about engineering animals that are resistant to common diseases. In 2014, for instance, Chinese scientists used genetic manipulation plus cloning to create cows that are resistant to the bacterium responsible for mastitis, a condition that causes udder tissue to become painful and inflamed. This research could improve the lot of livestock and save farmers billions of dollars in lost revenue to boot. A similar

It's possible to think about engineering animals that are resistant to common diseases

HOW DOES CLONING WORK?

A cell in an early embryo has something akin to a superpower. It can transform into any part of the organism, a skin cell perhaps, a muscle cell, a nerve cell or a blood cell. Before Dolly, everyone assumed that in mammals this process of specialisation, so-called 'differentiation', was irreversible. Dolly proved otherwise.

Scientists start with an egg cell ①. The nucleus (the part of the cell that contains the majority of the genetic material) is removed from the egg cell ②. A single differentiated cell, in this case an udder cell from an adult donor, is picked up by a tiny needle ③. The udder cell is injected into the egg cell and a small electrical pulse is used to fuse the nucleus into its new environment and to kick-start cell division ④. The egg cell and differentiated cell fuse. You can see in this image that the egg cell now has a nucleus (upper centre) ⑤. The embryo is implanted into the uterus of a surrogate female. She carries the clone to term ⑥.



TO CLONE OR NOT TO CLONE?

When it comes to ethics, some forms of cloning are easier to justify than others



According to Angelika Schnieke, chair of livestock biotechnology at the Technische Universität München in Germany, cloning is of immense value to biomedical

science. "It has allowed us for the very first time to make precise and controlled modification of animals," she says. The applications are endless. By combining gene editing with cloning technology, we should be able to create livestock that is less susceptible to illness and disease, improving animal welfare and the livelihoods of humans to boot. Cloning also promises to give us more accurate animal models of human diseases, along with organs that can be used for transplantation. Banning cloning would be unethical, says Schnieke. "If I can do something more precisely and I can use fewer animals it makes more sense," she says. "The world would be a better place for the animals and humans if we embrace this technology sensibly."

FOR

AGAINST



Those opposed to cloning raise several objections. For Helen Wallace, director of GeneWatch UK, the creation of Dolly was a watershed moment in our relationship with the natural world, "a significant further step towards seeing animals only as commodities to be created for our convenience." The fact that cloning still remains an inefficient process is also a concern. "Many animals are subjected to surgical procedures, whilst cloned offspring are often aborted or die prematurely," she says. Wallace's position on the use of cloning in livestock farming and for pets is clear. It should not be allowed. But even when the purpose of cloning is to improve animal and human health there needs to be more scrutiny, she says. "Alternatives should always be considered and non-animal testing methods further developed to be more widely available."

approach could be used to engineer cattle resistant to the parasite that causes sleeping sickness, a major constraint to livestock production in sub-Saharan Africa.

There could even be environmental benefits of cloning. Researchers at the University of Guelph in Canada have created Enviropigs, animals with a bonus enzyme that means they produce less phosphate in their manure and so are less polluting.

But for historian Garcia-Sancho, Dolly's real legacy is not to be found in creating vast flocks of identical farm animals or 'resurrecting' a favourite pet. This special sheep and the excitement she caused stimulated a lot of research and interest into human embryonic stem cells. Perhaps Dolly's biggest contribution was to aid the discovery, in 2006, that it is possible to convert adult cells into all-powerful stem cells without having to go through the hit-and-miss rigmarole of moving nuclei from one cell to another. "Science is very serendipitous," Garcia-Sancho says.

Henry Nicholls is a science writer and author. He tweets from @WayOfThePanda.

DISCOVER MORE



To watch an archived *Horizon* episode about why Dolly the sheep was created, visit bbc.in/1Tli8j2



RIGHT: Canadian researchers have cloned pigs that create more eco-friendly manure

10 WEIRDEST THINGS EVOLUTION LEFT IN YOUR BODY



Modern humans have been walking the Earth for around 200,000 years. Over the course of our evolution, we have adapted to all sorts of conditions and environments. But some of these adaptations have hung around for longer than we've needed them...

Words: Catherine E Offord



1

COCYX

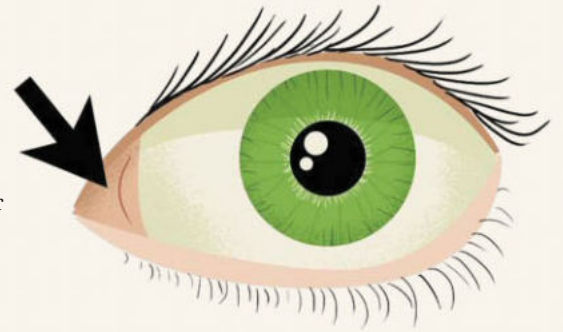
Before you were born, you had a tail – albeit only for a few weeks. All mammals develop a tail as embryos in the womb, but humans (except in a few very rare cases) lose it again before birth. The coccyx, or tailbone, at the bottom of your spine is this tail's last remnant.

2

THIRD EYELID

In the corner of your eye, next to the tear duct, is the remnant of a third

eyelid technically known as the plica semilunaris. In many reptiles and birds, and some mammals, this translucent 'nictitating' (blinking) membrane can be drawn horizontally across the eye for moisturisation, extra protection or to remove debris. In humans, it plays more minor roles, such as assisting tear drainage.



3

WISDOM TEETH

Most people only become aware of their wisdom teeth thanks to toothaches in their late teens and early twenties. These extra molars were probably used by our larger-jawed ancestors to grind up raw plant material. Now, these teeth are virtually useless, and their removal is one of the most common surgical procedures in the UK.

4

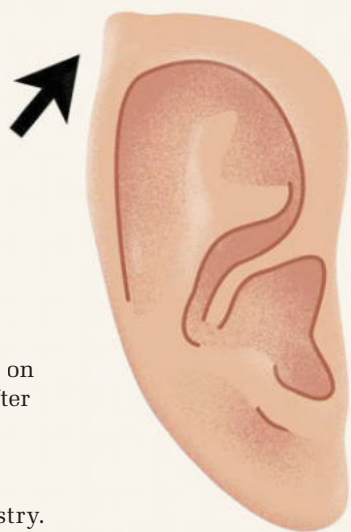
JACOBSON'S ORGAN

Also called the vomeronasal organ, this is an important smell sensor in many animals, from elephants to salamanders. Some studies suggest humans have a remnant of this organ at the back of the nose, but as there are no nerves connecting it to the brain, it's unlikely to play a role in our sense of smell.

5

DARWIN'S POINT

Around a quarter of the population has a small bump on the upper edge of the ear, known as Darwin's point after its description in Darwin's *The Descent Of Man*. The position of the bump matches the location of more prominent points in the ears of many of our primate cousins, providing another sign of our common ancestry.



6

PALMARIS LONGUS

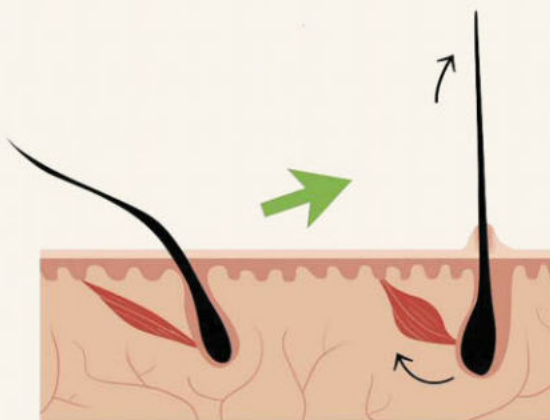
Around 85 per cent of people have a palmaris longus, a vestigial muscle running from the elbow to the heel of the hand. In some primates, this muscle assists climbing, while in cats and other predators, it retracts the claws. You can test if you have it by flexing your wrist and touching your fifth finger to your thumb – if it's there, it will pop up.



7

GOOSEBUMPS

Goosebumps appear when you're frightened, or a bit chilly, thanks to tiny muscles called arrector pili surrounding hair follicles in your skin: when these muscles contract, your hairs stand up. In humans, such hair-raising has little effect, but it could have made our furrier ancestors appear larger when threatened, and would have provided insulation in cold weather by trapping a layer of air by the skin.



9

AURICULARES MUSCLES

If you've ever seen someone wiggle their ears, then you've seen them use a set of vestigial muscles called the auriculares muscles. Cats, dogs and many other mammals use these muscles to move their ears and focus their hearing. Our ancestors all but lost this ability, making the muscles good for little more than the occasional party trick.

8

PALMAR GRASP REFLEX

Place an object in the hand of a baby under five months old, and the fingers will automatically close around it with a surprisingly strong grip. This reaction, known as the palmar grasp reflex, is a throwback to hairier times, when babies of our predecessors would have clung to their mothers by gripping their body fur.

10

PLANTARIS MUSCLE

The plantaris is a small muscle that plays such a minor role in humans that around 10 per cent of the population doesn't have it at all. Situated behind the knee, this muscle connects to the ankle via a long tendon that, in our more flexible primate relatives, can be used to make the foot grasp branches or pick up objects.



REACHING NEW HEIGHTS

A mile-high skyscraper proposed by Frank Lloyd Wright in 1956 was an impossible dream. But could modern building methods make it a reality?

Words: Rob Banino

PHOTO: KOHN PEDERSEN FOX ASSOC. AND LESLIE ROBERTSON ASSOC. FOR "NEXT TOKYO"



In 2045, Tokyo could have a mile-high skyscraper, as envisioned by architects Kohn Pedersen Fox Associates and Leslie E Robertson Associates

S

ixty years ago, renowned US architect Frank Lloyd Wright unveiled his plans for the Illinois Tower. Wright, then aged 87, was famous for audacious

designs, but the Illinois Tower was his most ambitious – a skyscraper extending a mile into the air.

Wright was not a fan of cities. So to protect his beloved rural landscapes from the threat of urban sprawl, he embraced the concept of concentrating people, their jobs and their lives in a contained area. “If we’re going to have centralisation, why not quit fooling around and have it,” Wright said when presenting his design for the Illinois Tower.

It was to be built in Chicago and would be a tower bigger than anything seen before – more than four times higher than the 381m-tall Empire State Building, with over 520 storeys and parking for more than 15,000 cars. But it was a fantasy. Given the materials and construction techniques available in the 1950s, there was no way that it could be a viable structure.

Wright died in 1959, just three years after presenting his mile-high tower. Since then, improvements in building materials and methods have seen skyscrapers grow ever higher, but we’ve yet to get anywhere near Wright’s 1,600m-high design. Currently, the 828m-high Burj Khalifa in Dubai is the world’s tallest building.

So is a mile-high skyscraper even possible to build?

TOWERING AMBITION

Roma Agrawal, a structural engineer at construction company Interserve who worked on the Shard (at 310m, the tallest building in London), thinks so. “The technology and the engineering are there to go as high as we want. The limitations are really only money and what we want as humans.”

And she’s not alone. “We don’t believe it’s a technological barrier,” explains David Malott, an architect of supertall towers with architectural firm Kohn Pedersen Fox. “We understand the technologies that would enable us to build a mile-high tower now. It’s going to look different to what Frank Lloyd Wright proposed but, nonetheless, we understand what it has to be.”

Wright’s design was thought to be impossible to build, so what do we know now that he didn’t?

“If you were to test Wright’s design, you’d find immediately that it doesn’t stand up to the wind,” explains Malott. “Advancements in aerodynamics – the understanding of how buildings behave in the wind – have allowed us to build taller than we have before. But very slender structures, like Wright proposed, have a tendency to flutter, in the same way that a flagpole does.” And if a structure flutters too much, it can shake itself apart. This is exactly what happened in 1940 with the Tacoma Narrows suspension bridge in the US state of Washington – it collapsed in winds of just 68km/h (42mph).

To prevent that, a building needs to be carefully shaped to work with the faster wind speeds encountered at higher altitudes. “If I took a square and just extruded it up, without stepping it or tapering it, that’s just about the worst thing that I could do in terms of aerodynamic design,” says Malott. “If you want the building to be more aerodynamic, you should be looking at tapering it in profile or chamfering or rounding the corners. And the higher you go, the more aerodynamic the building has to become.”

Tapered profiles and chamfered edges reduce the force that the wind can exert by smoothing its path across surfaces. But another way of doing that is to give the wind less surface area to strike, which is what’s been done on the 432 Park Avenue building in New York. This 426m-high skyscraper was completed in December 2015 and is the third tallest building in the US.

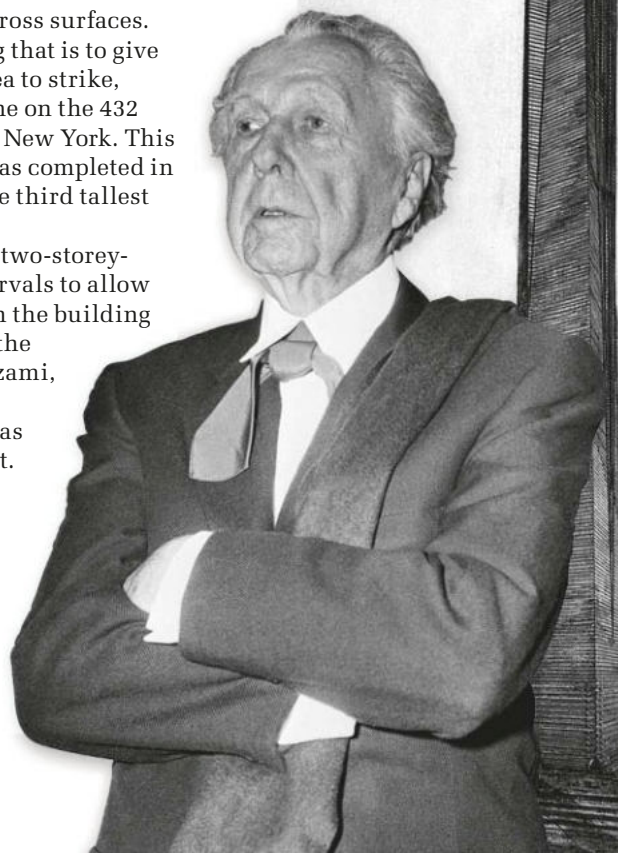
“We incorporated five two-storey-high gaps at various intervals to allow the wind to flow through the building rather than slap against the side,” says Kamran Moazami, a director at engineering consultants WSP, who was involved with the project.

AN IMPROVED RECIPE

A lack of understanding of aerodynamics wasn’t the only thing that was preventing Wright from turning his design into a reality. The materials available

RIGHT: The technology was not available to build the mile-high Illinois Tower in the 1950s

BELOW: Frank Lloyd Wright designed over 1,000 buildings, one of which was the Illinois Tower



to him in the 1950s simply weren't up to the task of supporting a structure of that size. But we still rely on those same materials – concrete and steel – today, so how come we're able to go higher now?

"Concrete strength has improved a lot," says Agrawal. "Concrete is just water, cement – a very fine powder made from burnt limestone – and aggregate, which is pebbles or bits of rock around 20mm in size. The fundamentals of the concrete recipe haven't really changed since Roman times. But what has changed is the quality of the ingredients and the way they're combined, because once we understood the chemistry behind the mix we could play around with it to make the concrete stronger."

So it's partly chemistry that's allowing us to build taller skyscrapers. And, according to Malott, further improvements are on the way.

"Traditionally, the downside to concrete is that it's prone to cracking,"

"You could build up to a kilometre, even up to a mile. But economically, something that tall is extreme – it's difficult to afford. You have to be a government or a rich organisation"

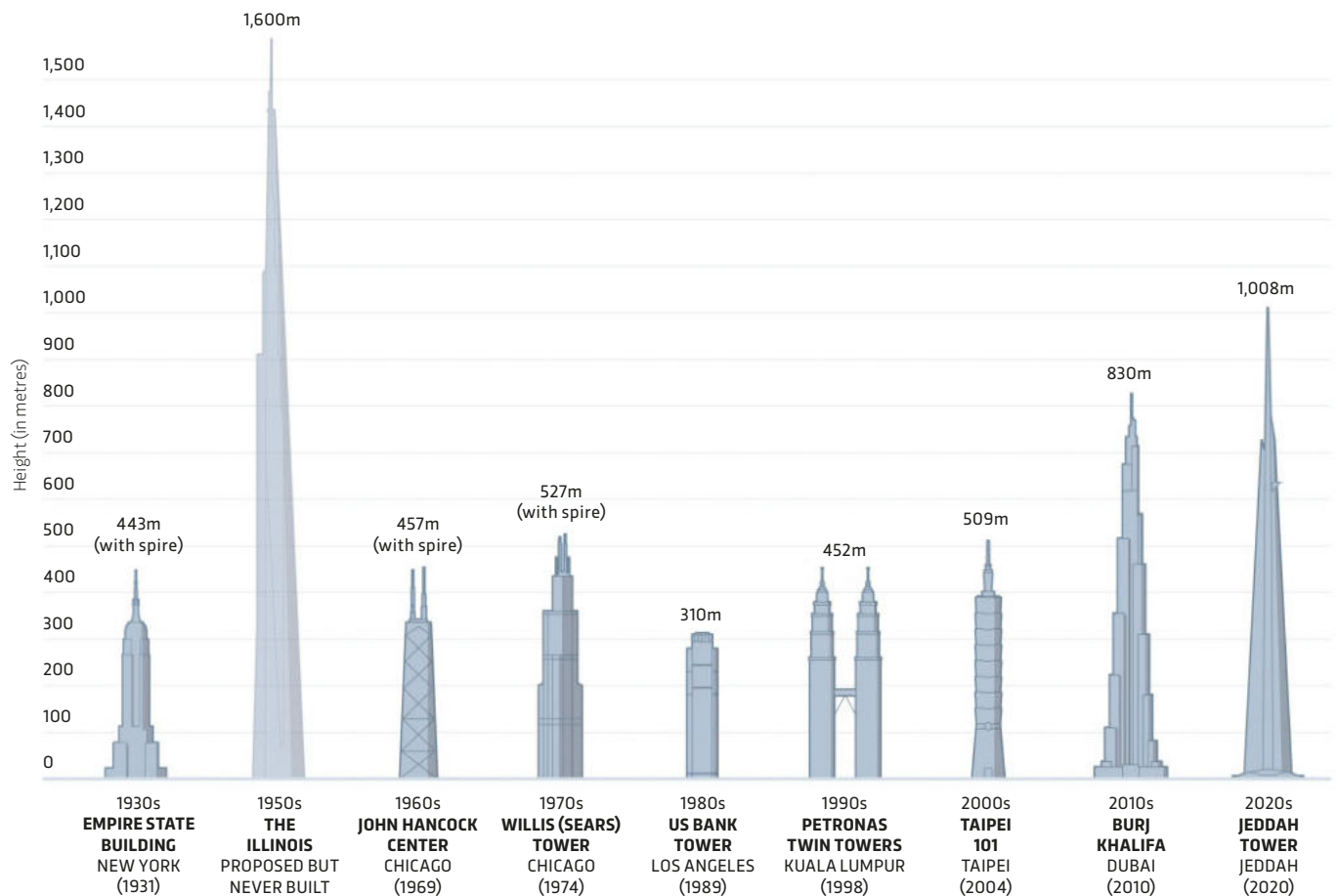
he says, "but now we're looking at putting polymers inside the concrete. Cracks expose the polymers to sunlight; they rupture under the UV light and release an epoxy [a kind of glue] that fills up the crack. There's also a group at Delft University of Technology [in the Netherlands] that's looking at adding bacteria into concrete that propagate to fill the crack when they're exposed to the environment."

With these advances in knowhow, methods and materials, the expert consensus is that we already have the means to construct a building equivalent to the Illinois Tower today. At least in theory, because there's one thing still holding us back: money.

"The technology's there. The material strength is there. You could build up to a kilometre, even up to a mile," says Moazami. "But economically, something that tall is extreme – it's difficult to afford. You have to be a government or a very, very rich organisation."

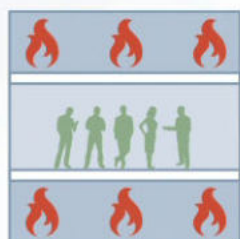
To give an idea of just how extreme the economics are, consider this: construction of the Nakheel Tower in Dubai began in 2008 with the laying of the 1,400m-tall building's foundations, at a cost of \$100m (£69m approx). Shortly afterwards, the global economy collapsed and the project was abandoned. And as offensive as the thought of \$100m worth of foundations being discarded is, it's nothing ●

SCRAPING THE SKIES



Tallest skyscraper built in each decade
(none were built in the 1940s)

MAKING A MILE-HIGH SKYSCRAPER

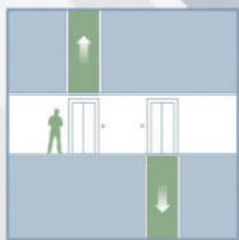


REFUGE FLOOR

Safe zones made from more robust materials with fireproof paint and specialised ventilation systems are created so people on the upper floors can shelter in the event of an emergency.

MAGLEV LIFTS

Alternative methods for travelling around the skyscraper could be provided by maglev lifts running vertically and horizontally along tracks on the outside of the building.

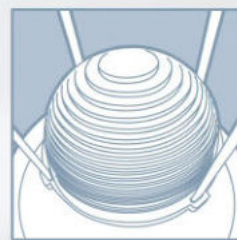


SKY LOBBIES

Since a single conventional lift is unable to span the distance from the ground floor to the top, certain floors are set aside as interchange areas where people can swap from one lift to the next to continue their journey.

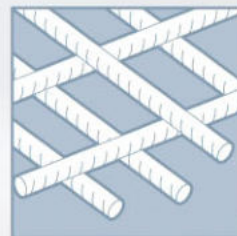
TAPERED PROFILE

WIND AND SOLAR FARMS



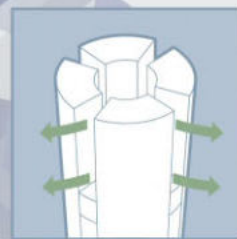
MASS DAMPER

Essentially a huge pendulum weighing hundreds of tonnes, a mass damper reduces swaying caused by wind or seismic activity. As well as preventing structural failure, they mitigate effects of motion sickness that swaying can produce.



CONCRETE

Steel cables running through concrete increase the material's compression strength, allowing for thinner walls and greater floor space. Adding carbon nanotubes into the mix could increase the concrete's strength even further.



AERO SLOTS

Vertical or horizontal cutouts on the building's exterior reduce the force the wind can exert by allowing it to pass through the structure.

● compared to the \$38bn (£26bn) that would have been spent if the construction went ahead.

THE HIGH LIFE

Assuming someone had the money, we could build a mile-high skyscraper. One has even been put forward by Kohn Pedersen Fox: the 1,699m-tall Sky Mile Tower, part of the Next Tokyo 2045 project in Japan. So the question becomes: *should* we build something

that tall? Would people actually want to live and work in such a place?

Studies of the residents of British tower blocks built during the 1960s and 70s showed that they were more prone to depression, feelings of alienation and marriage breakdowns than people in more traditional housing. And those buildings weren't anywhere near as tall as today's skyscrapers.

But those tower blocks also weren't designed to foster social interaction.

Architects designing today's skyscrapers go to great lengths to incorporate communal areas to help people socialise. Gardens and atriums also ensure that residents are close to natural light and the outside world.

But access to daylight and fresh air aren't the only concerns about supertall buildings. Access in general is an issue, especially as current lift technology is only capable of reaching 500m in one go. Aside from the energy and speeds

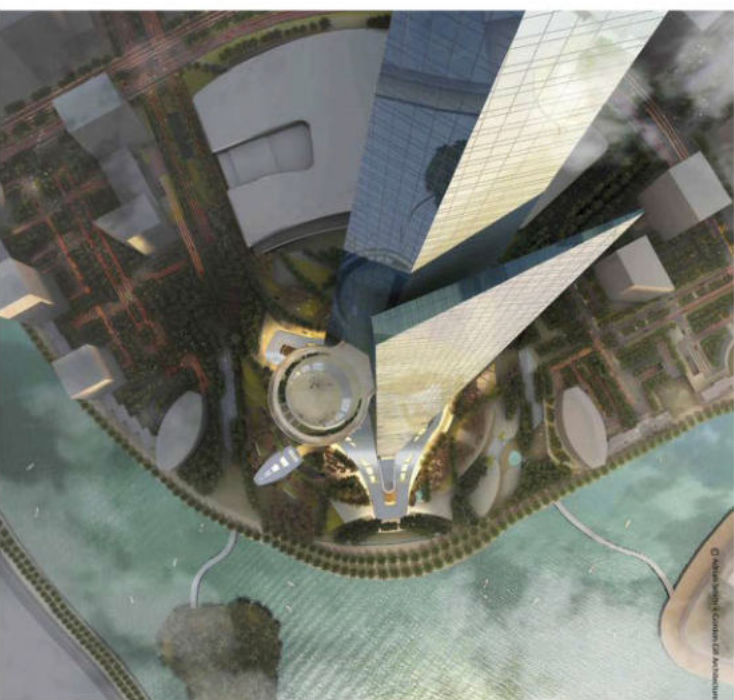
needed to run multiple lifts to the top of the building, the main problem is the steel cables that carry them. A cable long enough for a lift in a building taller than 500m would weigh 29,000kg – making it too heavy to support itself.

‘UltraRope’, a carbon-fibre-reinforced cable made by Finnish company KONE, is one possible solution (and is being used in the 1,008m-tall Jeddah Tower, due for completion in 2020). The other solution, currently being tested by manufacturers ThyssenKrupp, is to abandon cables altogether and instead use a chassis that travels on maglev tracks running both vertically and horizontally through the building.

But what happens when you can’t use the lifts, such as during a fire?

“Once you’re above 500m you’re not really leaving the building in one go,” says Malott. “We’ve done simulations

RIGHT AND BELOW: Upon its completion, Saudi Arabia’s Jeddah Tower will be the first building to top 1km in height



Cities continue to draw people from the surrounding areas, driving up land value

that show an evacuation from such a building will take one-and-a-half to two hours. So we design them for phased evacuation. Every 12 to 15 storeys there’s a refuge floor, a safe haven where the structure is hardened and there are no combustible materials [and people can wait to be rescued].”

According to Malott, once you go beyond a kilometre, phased evacuation isn’t an option because it takes up to six hours to get out. “You have to think about ways that the structure can last in a fire – it needs to be robust enough that if some columns or floors get burned through the entire structure isn’t disabled,” he says. “Technologically, it can be done but I think it’s more the psychological issue of people accepting they have to stay in the burning building.”

Ultimately, the question of whether we should build such tall buildings may be answered for us. Cities around the world continue to draw people from the surrounding areas, driving up land value and the potential returns for developers. And if we’re going to protect the countryside, as Wright originally intended to do with the Illinois Tower, building up instead of out may be our best and most sustainable option. **F**

Rob Banino is a freelance science journalist.

DISCOVER MORE



Find out how skyscrapers stay up in this BBC iWonder article by Roma Agrawal
bbc.in/1RUI5aW

FROM THE MAKERS OF **BBC FOCUS** MAGAZINE

THE SECRETS OF NATURAL REMEDIES



In this special issue, the editors of *BBC Focus Magazine* put natural remedies under the microscope. From acupuncture to yoga, argan oil to zinc, we ask scientists which techniques and treatments will help you live a happier, healthier life and which you ought to avoid.

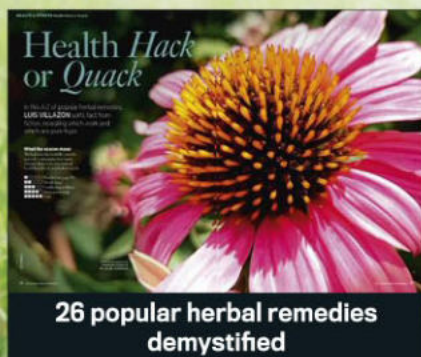
Inside you will find:

- ◆ The scientific verdict on current health trends
- ◆ Expert opinion from world-leading researchers
- ◆ Straightforward tips and tricks to stay healthy
- ◆ Insights on the future of medicine and well-being

**ONLY
£9.99
INCLUDING
FREE P&P***

Plus - subscribers to *BBC Focus Magazine* receive FREE UK postage on this special edition!

THE **FOCUS** COLLECTION



Order online www.buysubscriptions.com/natural
or call us on **0844 844 0257**⁺ and quote **NATHA16**

⁺ Calls will cost 7p per minute plus your telephone company's access charge. Lines are open 8am-8pm weekdays & 9am-1pm Saturday.

* Subscribers to *BBC Focus Magazine* receive FREE UK postage on this special edition. Prices including postage are: £11.49 for all other UK residents, £12.99 for Europe and £13.49 for Rest of World (please note this title is not available for direct order in the US or Canada but is available in all good retailers now). All orders subject to availability. Please allow up to 21 days for delivery.



ROBERT MATTHEWS ON... QUANTUM WEIRDNESS

"THE KEENNESS OF NUTTERS TO REACH FOR THE 'Q-WORD' HAS MADE LIFE TOUGH FOR RESEARCHERS"

Jim Al-Khalili's television documentaries take on challenging subjects without being

patronising or gimmicky. And that's why I'm a huge fan of his. As the host of *The Life Scientific* on BBC Radio 4, he does a great job of getting scientists to reveal what they do all day. And as an author, he explains tough scientific ideas with amazing clarity.

But while I envy his skill, I sure don't envy his celebrity. His website hints at the reason: it carries a polite notice saying in effect he can't check out claims for perpetual motion machines or time travel.

Like all science celebrities, Al-Khalili is a target for every crackpot with an email account. Worse still, he's an expert in quantum theory.

Everyone knows quantum theory is weird, so that's where everyone heads when looking for explanations of weird stuff like telepathy, homeopathy and parallel universes. What gets missed is the fact that quantum theory isn't just a grab-bag of buzzwords like entanglement and uncertainty. Each has a specific meaning and comes with 'terms and conditions' that show when it applies.

Take the New Age claim that quantum entanglement explains telepathy. For most scientists, this one's easy to deal with: there's no evidence that minds can communicate telepathically, and thus nothing to explain. But even if there were, entanglement still won't help. That's because despite its name, it doesn't involve communication between objects. Entanglement is all about how it's possible, using a very strict recipe beset with 'Ts & Cs', to make two objects behave as if they're the same object, even when separated by huge distances.

In a sense, then, entanglement is even weirder than telepathy, but it certainly lends it no credibility.

Ironically, the keenness of nutters to reach for the 'Q-word' at every opportunity has made life tough for serious researchers who suspect quantum effects may



explain genuine mysteries. For example, the ability of birds to migrate between continents has long perplexed scientists. Since the 1960s, it's been clear they have some kind of compass allowing them to navigate using the Earth's magnetic field. But how?

One possibility is that they can sense it through some delicate quantum effect on their biochemistry. Or at least it would be, were it not the case that such ideas are 'a romping ground for

charlatans', as one distinguished chemist once put it.

But some brave scientists have risked their reputation by taking it seriously, and now it seems that they're on to something. Studies of the European robin suggest its eyes contain molecules that can sense the Earth's feeble magnetism via quantum entanglement. If true, that suggests these birds have evolved a means of dodging those 'Ts & Cs' affecting quantum entanglement. That in turn may open the way to new quantum technologies able to cope with everyday conditions.

Meanwhile, researchers have found evidence for weird quantum effects driving other natural effects, like photosynthesis, as Jim Al-Khalili explains in his brilliant book *Life On The Edge*.

Now it seems even tap water has a few quantum tricks too. H_2O has many strange properties; for example, it doesn't shrink on freezing, but expands. Now researchers have found that it uses quantum energy conjured up out of nowhere when it bonds to other water molecules.

I'm praying Jim Al-Khalili's next book covers all this, as it can't be long before I'm in the pub and get asked: "So how does quantum theory affect my pint, then?" ☯

Robert Matthews is visiting professor in science at Aston University, Birmingham. His latest book *Chancing It: The Laws Of Chance And What They Mean For You* is out now (£14.99, Profile).

DISCOVER MORE



Listen to episodes of *The Life Scientific* at bit.ly/life_scientific

NEXT ISSUE: ANIMAL EXPERIMENTS



PHOTO: GETTY

ARE MY GENES TO BLAME IF MY JEANS DON'T FIT?

IN THE UK, 64 PER CENT OF ADULTS ARE OVERWEIGHT OR OBESE. MANY EXPERTS WARN WE ARE FACING A CRISIS. BUT IS THE SOLUTION MORE COMPLICATED THAN 'EATING LESS AND MOVING MORE'?

WORDS: GILES YEO

Giles is the principal research associate at the MRC Metabolic Diseases Unit, University of Cambridge. He tweets from @gilesyeo.

COMPLEMENTS
HORIZON
**WHY ARE WE
GETTING SO FAT?**
BROADCAST ON



R

Recently, a small supermarket opened at the hospital where I am based. It was one of those places that primarily sells convenience food and drink. I was there one day getting a sandwich for lunch, with what appeared to be everyone else in the hospital. I was standing in line behind a nurse, who had a salad and a yoghurt clutched in her hand. This nurse had clearly started her foraging expedition with all the best will in the world, and if the cash till had been right there, she would have made it out of the shop with an undeniably healthy lunch. However, as the line snaked, in Disneyland-like fashion, inexorably towards the checkout, so began the obstacle course of chocolates, sweets, crisps and other temptations that are located, as is typical, close to the tills. The nurse looked longingly at every treat but managed to shuffle past each time. This must have happened 10 or more times. In my head, I was cheering her on:

"Come on! You can do it!"

Finally she made it to the till, and as her guard dropped, the cashier pounced with a deadly offer: "Would you like some freshly baked cookies? Two for one today?" And the battle was lost. The nurse walked out with almost 800 extra calories in cookies.

Who is to blame in this scenario? Do we blame the nurse? Do we blame the shop for putting the food by the tills, or the cashier for making the offer? Do we blame the government for not compelling the supermarket to stop putting junk food by the tills? Should we be throwing stones at all?

Since time immemorial, the control of food intake and

body weight has been thought to be simply an issue of self-control and willpower. Gluttony is, after all, one of the 'seven deadly sins'. So as obesity has become an increasing public health problem, reaching epidemic proportions in most developed and emerging economies, society in turn blames the overweight and obese for a lack of moral fortitude.

Obesity is perceived as quite a simple problem. This is the prevailing view, and it is easy to see why. People just have to eat less and move more and they will lose weight. It is one of the fundamental laws of physics; you cannot magic calories out of nowhere, and likewise you cannot magic them away. However, this sage piece of advice that your grandmother could have given you is clearly not working as we're getting fatter and fatter.

The problem is that we have been focusing on the wrong part of the equation. The question to ask is not *how* we have become obese (we do eat too much and move too little), but *why* some people eat more than others. The answer to this question is incredibly complex, and we are only now beginning to understand the powerful biological and genetic influences on food intake.

HORMONES AND HERITAGE

We now know that there are hormones that circulate in the blood and signal to the brain, letting it know the nutritional status of the body. Broadly speaking, there are two sources for these signals. The first is hormones secreted from fat, our long-term energy stores, letting our brain know how much we have on board. This is absolutely critical information because how much fat we have is, basically, how long we will last without food. The second is hormones secreted from our stomach and gut. These are short-term signals that let our brain know what we are currently eating and what we have just eaten. The brain integrates these long- and short-term signals, and influences our feeding behaviour at the next meal. This is our 'fuel sensor'. ●

It is one of the laws of physics; you cannot magic calories out of nowhere, and likewise you cannot magic them away



LEFT: Humans struggled for food throughout much of history, so we're programmed to eat plenty when it's available

BELOW: Today, we have a huge choice of food available and are bombarded with incentives to make us buy more



● Yet, while all humans (all mammals in fact) share this ‘fuel sensor’, we come in different shapes and sizes. It is becoming clear that variation in body shape and weight is powerfully influenced by genetics.

One of the most invaluable tools in determining the genetic heritability of specific traits is the study of twins. Identical twins are genetic ‘clones’, while fraternal (or non-identical) twins share 50 per cent of genetic material, as you would with any of your siblings. Thus, with the study of enough twins, both identical and fraternal, one could look at any trait that could conceivably have a genetic element, such as eye colour, hair colour, foot size, height or weight, and calculate how heritable each trait might be.

As you might imagine, traits such as eye colour and hair colour (peroxide aside) are almost entirely genetically determined with very little environmental influence. In contrast, while a trait like having freckles is clearly genetically influenced; whether, where and how many freckles appear will be down to how much time one spends in the sunshine. What might be surprising to most people is that the heritability of weight is equivalent to that of height! No one would dispute the fact that height is genetically determined: tall parents = tall children. It is also well known that skeletons and written records show that human beings today are inches taller than humans just a century or two ago. Why have we become taller as a species? Change in diet, environment, and lifestyle.

It is the same argument with body weight, except that the changes have happened over a shorter period of time. We are now more obese as a species compared to 30 years ago because of changes to our diet, environment and lifestyle. But it does not change the fact that if our parents are overweight, we are much more likely to be overweight.

What might be surprising to most people is that the heritability of weight is equivalent to that of height!

A FAT MAN'S BEST FRIEND

Genetic approaches offer an effective tool for characterising the mechanisms of food intake and body weight control, and allow us to understand how these may become defective in the obese state.

Over the past 20 years, one of the pathways that has been highlighted by genetic studies is the fat-sensing ‘leptin-melanocortin’ pathway. The hormone leptin is produced from fat and signals to the brain how much fat is stored in the body, while the melanocortin pathway in the brain senses leptin levels and goes on to influence food intake. We know this pathway

is absolutely critical in the control of food intake, because genetic disruption of either the leptin or the melanocortin pathway results in severe obesity in humans. When this pathway is disrupted, the brain thinks you have less fat than you actually do, driving you to eat more to gain more fat. This fat-sensing pathway is critical for all mammals, including, as we have recently discovered, dogs.

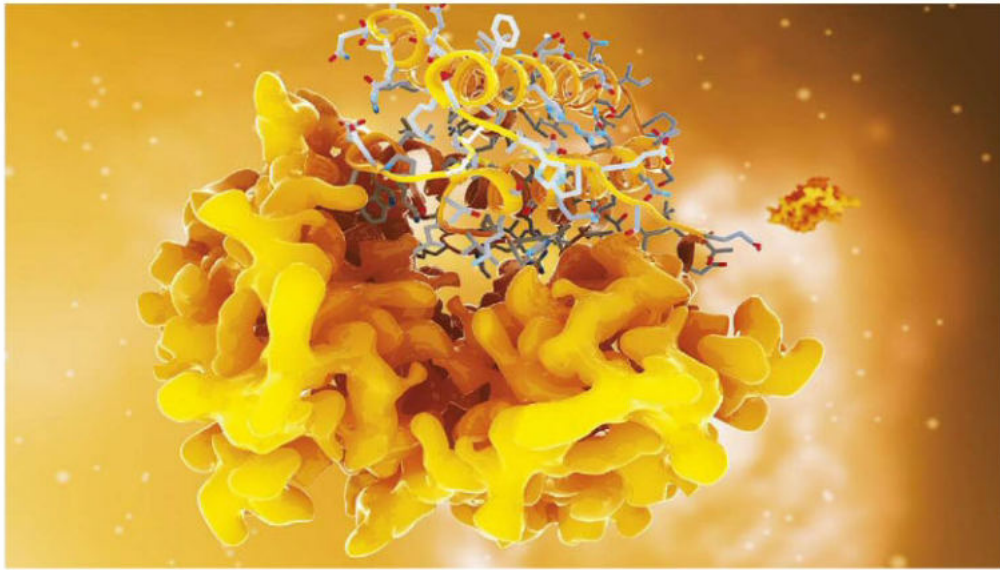
Labradors, the most popular pet dog breed in the UK and North America, are known to be very food motivated and are therefore prone to obesity. We found that nearly a quarter of Labradors have a genetic disruption in the melanocortin pathway that makes them more food motivated and obesity prone than other dogs. The main reason why Labradors are such popular dogs is their lovely disposition and trainability. These defining characteristics are also the reason why they are overwhelmingly used as guide dogs for the blind. These dogs are highly trained, often with – you guessed it – food rewards. Nearly 80 per cent of guide dog Labradors carried the genetic mutation, so we think that their disposition and trainability is down to their genetically driven motivation towards food.

IT'S ALL IN OUR HEAD

From the human perspective however, genetic disruption of the melanocortin pathway resulting in severe obesity remains a rare occurrence. The ‘common’ obesity that currently blights us is more likely to be ‘polygenic’ in origin, with many subtle genetic variants. Each by itself has an almost imperceptible effect, but together they have a cumulative measurable consequence. We now know of over 100 genes that are linked to obesity. These genes, which include many found in the melanocortin pathway, mostly function within the brain to influence food intake. The evidence tells us that having more risk variants of these genes makes your brain slightly less sensitive to hormones from the fat and gut, with the effect that some of us simply feel a little more hungry all of the time.

Not eating when you are not hungry is really easy. It requires no effort. Have you, however, tried to stop eating when you are still hungry? It's difficult, even for one meal, because it's just not what we are designed to do. We have evolved to eat when there is food, not to stop.

So here's the thing. Thin people are not morally superior with the willpower of forged steel, they just feel a little less hungry, so get full up more easily. Equally, obese people are not morally bereft, lazy or bad. Rather, they are fighting their biology. In essence, an obese brain thinks that you have slightly less fat than you actually have, and you ate slightly less than you actually did the last time round, leading to you eating more in the next meal. Now you don't eat twice as much as someone else. You may only be eating ●



LEFT: The hormone leptin is produced from body fat and tells the brain how much fat is stored in the body

BELOW: Almost a quarter of Labradors carry a genetic mutation that makes them food-motivated – and therefore prone to obesity



● 5 per cent more. But a little more every day adds up to a huge difference over a lifetime.

THE 'OOOOOOOOH' FACTOR

Given the importance that eating has on keeping us alive, our brain has evolved strategies to make sure that it also feels 'good' or rewarding to eat; the 'ooooooooh' factor. This is easily illustrated by the all too familiar 'pudding stomach', despite already feeling full from the previous courses. Certain foods, such as typically energy-dense desserts, trigger the rewarding feeling better than others. This gives us the important motivation to make sure we store all the extra energy we can, ensuring sufficient fuel stores to chase down the next antelope. Having evolved over hundreds of thousands of years to stay alive through multiple famines, any increase in motivation, however small, to continue to search for food was an evolutionary advantage. The rewarding feedback from food that tasted good, and which was presumably not poisonous, was useful in guiding the development and entrainment of our eating behaviour.

There is still the strongly held belief in many quarters that we are in full 'executive control' of our own eating behaviour, that the environment is responsible for our shape and size, and our genes, our 'nature', has a minimal effect. However, it is crucial to remember that the drive to consume food is one of the most primitive of instincts to promote survival. It has been shaped through millions of years of evolution and has provided living creatures with mechanisms to adapt and respond to times of nutrient scarcity. Thus, I would argue that to be overweight in our current environment is indeed the natural, even highly evolved, response. The main issue is that the current

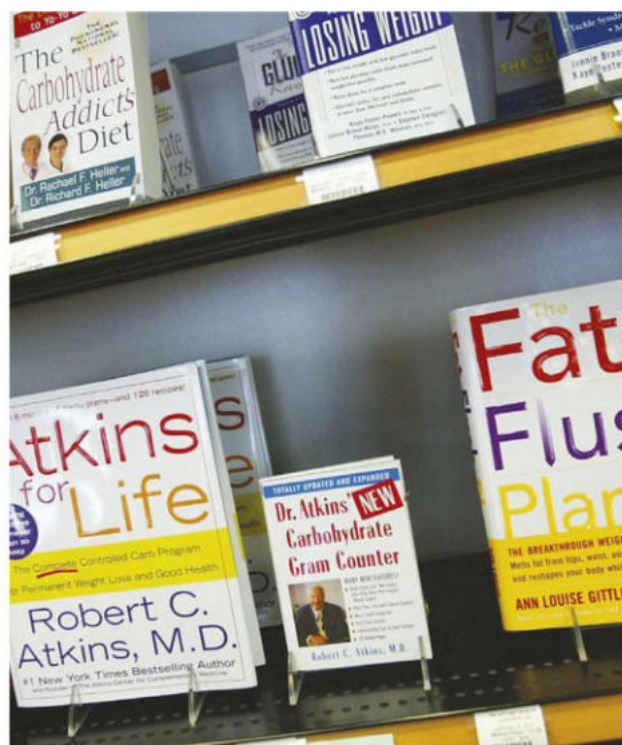
environment, such as the lunch obstacle course faced by the nurse, in which energy-dense treats and stimulatory food cues are ubiquitous, coupled with concurrent changes in lifestyle, is at odds with the millennia of austere surroundings to which we have adapted. This has consequently pushed obesity to become the serious problem it is today. I am fully aware that without this 'obesogenic' environment, most of us would not be overweight or obese; but to deny the central role that our genes have played in our response to this environment is unhelpful as we strive to tackle one of the greatest public health challenges of the 21st Century. ●

I would argue that to be overweight in our current environment is indeed the natural, even highly evolved, response



ABOVE: Jamie Oliver is one celebrity chef who is trying to tackle obesity by encouraging healthier eating habits and lifestyle changes

BELOW: There is an enormous consumer appetite for recipe books filled with advice on healthy eating and diets – but we're still getting fatter



PHOTOS: PRESS ASSOCIATION, GETTY



Pearson

Join our Assessment Associate Team

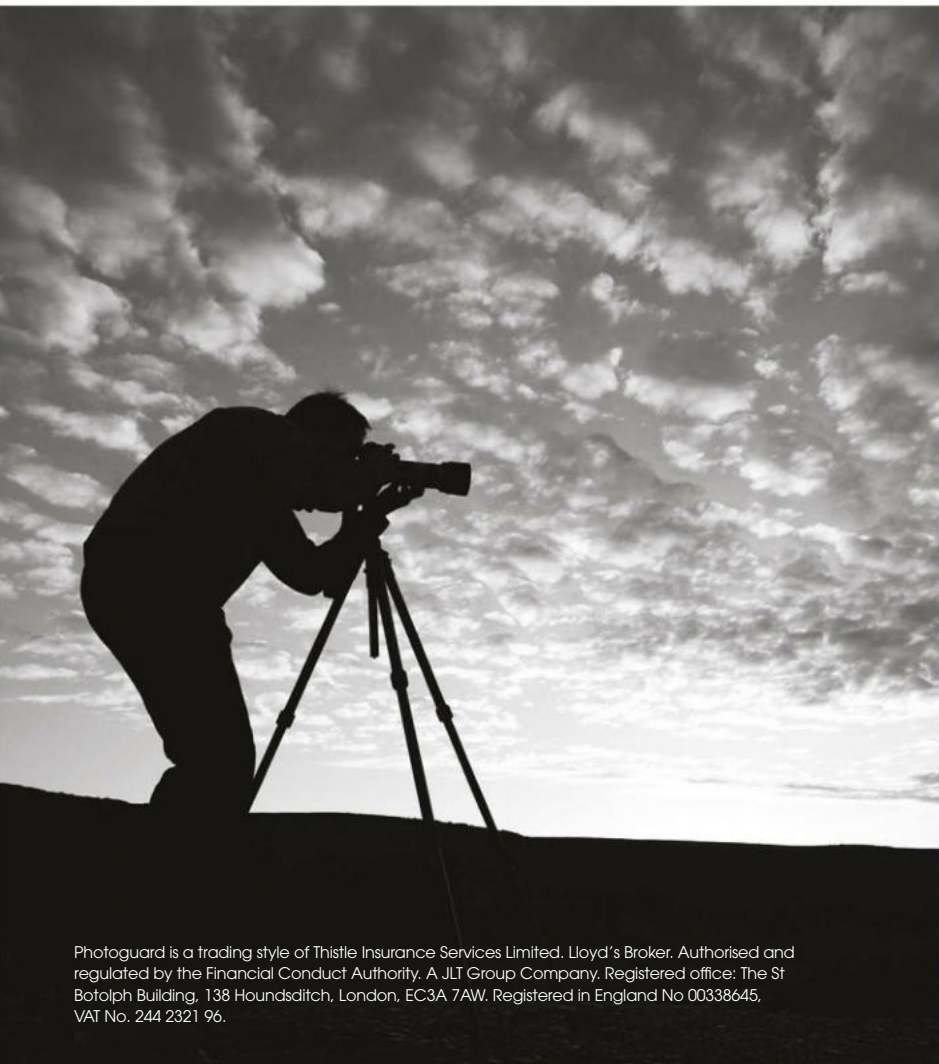
Pearson have exciting opportunities for science teachers to become Standards Verifiers for our BTEC in Applied Science. We are keen to recruit teachers across the UK who are currently teaching or recently retired.

This is an excellent opportunity to:

- Develop your understanding of assessment
- Interact with fellow educational professionals
- Inspire fresh ideas and approaches to teaching your subject
- Boost your income



For more information and how to apply, please visit our website www.edexcel.com/aa-recruitment or email us at aaresourcing@pearson.com



Whilst you frame the perfect shot...

...let us protect your passion.

Photoguard provides insurance for theft, accidental damage, hire costs* and 20 days worldwide cover as standard – keeping you doing what you love.

0333 004 6555

www.photoguard.co.uk

*Following a successful claim

Photoguard is a trading style of Thistle Insurance Services Limited. Lloyd's Broker. Authorised and regulated by the Financial Conduct Authority. A JLT Group Company. Registered office: The St Botolph Building, 138 Houndsditch, London, EC3A 7AW. Registered in England No 00338645, VAT No. 244 2321 96.

Photoguard
insuring the UK's photographers

EVERY

SECOND

COUNTS

On the track, pro cyclists use science to trim their times. We find out how well the tech works

Words: James Witts

T

and, of course, tech. Chris Froome and co ride bikes sculpted by computational fluid dynamics software and wind tunnels, while their clothing and nutrition are devised by some of the

he Tour de France and other high-profile cycling events are dripping with sweat, muscle and single-digit body fat. That

brightest engineers and scientists. For the professionals, there's little doubt that all this preparation makes a difference – just look at the success of British teams of late. But in the real world, how much quicker can these carbon steeds and 'high-energy' foods really make you?

To find out, I, James Witts, one-time editor of *220 Triathlon*, author of *The Science Of The Tour De France* and part-time cyclist, would ride a route twice. On the first run, I would adorn myself in casual clothing and perch atop a modern



but old-fashioned frame forged from steel. I would fill myself with ale and traditional grub. Then, a week later, on the second run, I would climb aboard an all-singing carbon number, while dressed in advanced materials and fuelled by a diet that's all about maximising energy. During the challenge, I'd also measure heart rate and speed via the advanced Garmin 735XT.

AERO VS URBAN

In the urban corner, we have the Bobbin

Noodle – 'a super-stylish urban machine' – with just one gear and a frame constructed from steel. In the other corner, we have the carbon-framed Giant Trinity Advanced Pro 2, similar to the bikes used by professional team Giant-Alpecin.

Shoreditch-saddling single-speeds are designed for simplicity and ease of use. No gears, no transmission system – just one gear to assist you from A to B. Yes, it means any of nature's dimples can leave you pushing your Noodle, but for urban

travelling on flat terrain, they're ideal. What they're not, unless you possess the thighs of Chris Hoy, are speed machines.

Unlike the Pro 2. Aerodynamic bikes are all curves and concealment in search of streamlined speed. As a cyclist, you're faced with a number of resistive forces. These are the rolling resistance of the tyres, friction in the chain and bearings, and the aerodynamic resistance to motion. In fact, at speeds over 48km/h (30mph), aerodynamic drag of the bike and rider has been measured at 96 per cent



Stopping to pose for photo shoots probably didn't help improve James's time

Loose-clothing equals drag, so apparel that leaves little to the imagination is de rigueur



URBAN CRUISER

Bobbin Noodle single-speed bike £380

Rapha Essential Polo £80

Café du Cycliste Paulette shorts £90

Quoc Pham Urbanite shoe £169.99

Boss watch £200

Hairspray £1.99

TOTAL £921.98



cent of total resistance. So anything the sports scientists can do to reduce drag, the better.

"Drag is primarily down to two aspects for the cyclist," Rob Lewis of computational fluid dynamics specialists TotalSim told me. "One is skin drag, which is the friction of the air rubbing over the surface. The other is pressure drag. That's harder to explain but, essentially, is why a brick has more drag than the same-sized object but in a more streamlined shape."

A blunt, irregular object disturbs the air flowing around it, forcing the air to separate from the object's surface. Low-pressure regions from behind the object result in pressure drag against the object. With high pressure in the front and low pressure behind, the cyclist is literally being pulled backwards. It's why teardrop shaping is popular in cycling. "The difference between round tubing and streamlined tubing goes back to the 50s," says Lewis. "It's proven that airflow is more turbulent passing over round objects compared to a smooth airfoil, which is essentially a tapered tube."

A cylinder experiences 20 times more drag than a teardrop shape, so you could have a cylinder that's 10mm wide and it'll create the same drag as an airfoil shape that's 200mm wide. In short, there's a huge advantage of tapering a shape, as seen on the Giant, so the air can flow around it and then recover.

So how do both feel over the test course? Well, you can see where the single-speed gets its name, bobbing along nice and leisurely. The Pro 2, on the other hand, flew. Well, it did once I'd got it up to speed and acclimatised to the aerodynamic position. You're pushed further over the handlebars, which is disconcerting at first but soon makes pedalling seem effortless.

Where the Bobbin has a clear advantage over the Pro is handling. The single-speed conforms to every twitch; the Pro is tanker-like when it comes to cornering. Thankfully our test run remained obstacle-free, as a lively Labrador could have curtailed my ride – and possibly its own life – early. There's also the less-techy issue of gears. A whopping 22 of them on the Giant versus one on the Bobbin.

SKINSUIT VS SPORTS CASUAL

Aboard my Bobbin I adorned clothing from uber-trendy Rapha (polo shirt) and

THE ROUTE

Nearly 10 of Bristol's finest miles provided the testing scenario. Here's the course breakdown...

One of the most common cycling distances is the 10-mile time trial. Just you against the clock. That's why I completed the 3.6km lap four times, the 14.4km course just shy of 10 miles (16km). Ashton Court in Bristol provided the

perfect venue, offering relatively car-free roads and smooth roads. Well, it does at certain times of the day, so each ride took place at a relatively quiet 8am. Thankfully, the weather gods played ball, with conditions very

similar over both tests. The route included gentle gradients, starting at 16m above sea level and reaching a peak of 106m. Each bike isn't an out-and-out climber but it added spice and effort to the time trials. It also

meant downhill, which offered an effortless platform to see just how fast each could roll when propelled by gravity rather than leg power. This turned out to be the key area where the Giant squashed the Bobbin.



"If I gaze into the middle distance, I won't have to focus on how tight this suit feels..."

AERO ADVANCES

Giant Trinity Advanced Pro 2 £2,699
Castelli Sanremo 3.2 speedsuit £210
Oakley EvZero glasses £140
Shimano cycling shoes £100
Garmin 735XT multisport watch £359.99
Lazer Wasp helmet £249.99
Madison Lycra overshoes £16.99
Beet It Sport drink £2.49 per bottle
Sodium bicarbonate 95p
Energy gel £2.49

TOTAL £3,799.41



Café du Cycliste (shorts) – both garments designed to 'add comfort and style to any ride'. They offer a hint of performance by employing elastane and polyester for both ease of movement and wicking abilities (transferring sweat from the body to air for cooling purposes).

On the Giant, I elected for the Castelli Sanremo 3.2 skinsuit. Its aim is simply to carve through the wind, no matter how silly it makes you look. Loose-clothing equals drag, so apparel that leaves little to the imagination is de rigueur. But I discover no stone's left unturned when it comes to material marginal gains.

"There are a couple of things you can play with when it comes to speedsuits," exercise physiologist David Martin informed me. "You can keep the fabric smooth to carve through the air. Or you can rough up the fabric, maybe putting dimples on it like you would a golf ball. That creates mini trips of airflow so it hangs onto the surface longer and, in turn, lowers drag."

The Castelli employs a mix of the both and, once my internal organs returned to their original position, it certainly ●

● added to the feeling of speed. The fact it pulls on your shoulders ever-so slightly means you fall onto the aerobars more naturally. In fact, down below it's actually more soothing than the urban shorts, as the padding (chamois) makes up for the unforgiving seat.

What's clear is that clothing counts; in fact, so much emphasis is placed on clothing apparel these days that the Australian Institute of Sport are creating exact replica mannequins of each rider in their professional WorldTour team. Why the dolls? So that seamstresses and technicians can design and test bespoke skinsuits based on each athlete's exact vital statistics. This preciseness is reflected in the visually questionable but practically fast Castelli.

BEETROOT VS FRY-UP

Two-and-a-half hours before each test I had breakfast. On Urban Day, it's the full works. Two sausages, two rashers of bacon, mushrooms... You get the picture. Doffing my cap to health, though, eggs were poached and bread was of the granary kind. To mimic the urban-y feel, the night before I took one for the team and drunk three ales – what else but the craft variety.

On Pro Day, I consumed the traditional athletic offering of porridge. This releases carbohydrates slowly, fuelling high-intensity efforts. (Conversely, during the winter, professional cyclists will ride over four hours on water alone to boost fat burning.) I had chia and pumpkin seeds for antioxidants and good fats. And, of course, skimmed milk. I also consumed the seemingly less-techy beetroot and bicarb...

The first was a 70ml shot of Beet It containing 98 per cent beetroot juice and 2 per cent lemon. Beetroot juice and its performance-enhancing properties have received a great deal of press these past few years. The idea is that, when digested, nitrates within the beetroot flow into a biochemical pathway within the body that converts them to nitric oxide. Studies have shown this conversion has the effect of reducing oxygen cost of exercise; in other words, making things feel easier.

That's all very well but I don't like beetroot, let alone its juice. But with fingers clipping nose, I consume in tequila fashion. Not surprisingly, you wouldn't serve Beet It to anyone apart

from high-performance seekers like those in professional cycling. Still, by the time I begin riding, my tastebuds have recovered.

The pre-test menu also includes an energy gel for a final sugary hit and sodium bicarbonate – yes, the fizzy white powder you bake cakes with. Why? Well, when you exercise hard, your body can't send enough oxygen to working muscles to maintain power output. Your body is a clever vehicle, however, and can produce energy without the presence of oxygen (anaerobically) to make up the shortfall. But this produces lactate, which raises the pH of your blood. That's where sodium bicarbonate comes in. Because it's an alkaline, it neutralises the acidic threat from intense exercise and, in theory, means the rider can work harder for longer.

Numerous cycling teams, like Mark Cavendish's Team Dimension Data, use this nutritional strategy in time trials, and its use is supported by a number of studies. A 2013 article in the

Journal Of The International Society Of Sports Nutrition saw eight cyclists given either a placebo or 0.3g of bicarbonate per kilogram of bodyweight 90mins before a power test. The scientists discovered that bicarbonate supplementation increased critical power output by a staggering 23.5 per cent. Which is great – but in reality, it tastes pretty disgusting (which is why teams would use pills not powder). Thankfully, things settle down and I'm away...

But does this high-tech diet work? Well, I certainly feel fresher and

We're not sure how 'urban' dinosaur socks are





Being... forced...
downwards...
by... shirt

physically lighter with the pro set-up, porridge and energy gels not surprisingly digesting easier than a fry-up and crisps. Dehydration from the previous evening's urban exploits don't help, either, with a hint of nausea accompanying the ride. Feelings are matched by facts as my urban muscles feel like they're riding through treacle and my heart is beating faster than Bradley Wiggins descending Alpe d'Huez. Thankfully, things stay south where nature, the landlord and butcher intended.

My high-tech set-up also includes an aero helmet, which follows a similar aero template to the tubing, and though feels compressed at first, is actually comfy; 'aero booties' smooth out airflow and are like slipping on PVC gloves for your feet (if you can imagine such a thing!); and purportedly the lightest-ever cycling sunglasses in the world from Oakley.

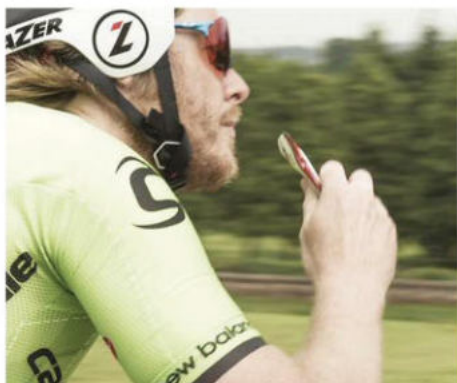
THE RESULTS

Despite the compressed torso, slightly aching shoulders and ridiculous-looking headwear, the 14.4km test loop was ticked off significantly faster in the high-tech gear compared to the single-speed urban set-up. The former I registered 31.46mins at an average 27.2km/hr. On the Bobbin, that finish time extended to 34.51mins at an average 24.8km/hr. So a whopping difference of 3.05mins. Why? Well, the aerodynamic gear certainly made a difference; I felt more tired on the Bobbin, partly due to its 'sit-up-and-hit-me-wind' set-up and partly due its single gear. As I was measuring urban time on my Boss analogue, I also didn't pace as well as I did with the Garmin and really tailed off at the end. But that extra speed comes at a significant outlay, with each of those 185 seconds saved costing an extra £15.55. When you're a pro and paid to ride, that's irrelevant; when you're a 39-year-old father of two, balancing work, family, bills, cycling and ale, that's everything. So thanks Froome and co but I'll take the Bobbin and cruise down the Red Lion. 🏆

James Witts is a freelance journalist who specialises in sports, science and technology. He tweets from @james_witts.

DISCOVER MORE

To find out more about the secrets of pro cycling, buy James's book *The Science Of The Tour De France*, out now (£17.99, Bloomsbury).



FROM THE MAKERS OF **BBC FOCUS** MAGAZINE

THE **BIG BOOK** SERIES

CARS OF TOMORROW

Future car tech, and how it's already shaping our daily drives



INSIDE: A shape-shifting BMW with X-ray vision; why Tesla's upcoming Model 3 could be your next electric car; how your car will read your mind; virtual reality showrooms; how to print a car, plus a buyer's guide to all the hybrid, electric and fuel cell vehicles on sale today.

PLUS – subscribers to *BBC Focus Magazine* receive **FREE UK POSTAGE** on this superb special edition!

**ONLY
£9.99**
inc FREE UK
POSTAGE*



Autonomous
tech: what we
have now, and
what's next



The robotic
racing series
coming this year



Why do V8s
sound good? Plus
more questions
answered

Order online www.buysubscriptions.com/cars
or call us on **0844 844 0257[†]** and quote **CARHA16**

[†] Calls will cost 7p per minute plus your telephone company's access charge. Lines are open 8am-8pm weekdays and 9am-1pm Saturday.

*Subscribers to BBC Focus magazine receive FREE UK POSTAGE on this special edition. Prices including postage are: £11.49 for all other UK residents, £12.99 for Europe and £13.49 for Rest of World. All orders subject to availability. Please allow up to 21 days for delivery.



HELEN CZERSKI ON... **SUGAR SCIENCE**

"THIS IS THE WONDERFUL THING ABOUT SUGAR. IT CAN EXIST AS BOTH A CRYSTAL AND AS A GLASS"

S

ugar had never been this frustrating before. My friend Sarah and I were prowling around the pan of sweet, melting crystals, desperate to stir it all together. Siobhan, who was following recipe instructions, was stern. "Don't touch it!" met our ears every time we

got too close. Sugar looks simple, but it's got the potential to take on different guises. Sarah and I were convinced that this batch was heading straight for the guise called 'burnt', but Siobhan was on a mission to do something more elegant: turn sugar into glass.

Each molecule of the sugar is made up of two components: glucose and fructose. Together, these make up sucrose: 45 atoms arranged in two linked rings. Even though that gives the sucrose quite a complicated shape, these molecules can still stack up perfectly on top of one another, locked into a rigid structure called a crystal. This is why sugar glints in sunshine – the stacks can have flat sides that reflect light like tiny mirrors. This is as simple as sugar gets. The complications that follow as you heat, cool, and mix these molecules fill recipe books, and keep the confectionery industry in business.

Siobhan had put dry sugar into a pan by itself and left it on the heat. My urge to stir came from my conviction that the heat was going to start chemical reactions in the hottest crystals, breaking them down into the acrid substances we associate with burnt food. But as we watched, occasionally sneaking in a quick stir when Siobhan wasn't looking, the sugar molecules heated up and became mobile enough to drift away from the crystals, forming a pool of melted sugar at the bottom of the pan. Nothing burned.

Afterwards, I looked up the temperature at which sugar melts, and was surprised to find that it's not simple. If you heat sugar slowly, it appears to melt at a lower temperature. For most substances, it's a fixed single temperature. But it seems that if you heat sugar slowly, chemical reactions start to happen, breaking up the sugar molecules. Those broken molecules can no longer hold their place in the crystal, and so all the molecules escape into liquid form at a lower temperature than they should.

Siobhan eventually let us stir the sugar, and the colourless liquid became a rich, dark brown: a caramel. If we left it in the pan to cool slowly, the mobile molecules would continue to jostle each other, slowing their dance



as the temperature dropped. Eventually, they would find their way back into the stack pattern to form new crystals. But Siobhan poured the whole lot over crushed nuts on a metal sheet, cooling it far too quickly for the molecules to rearrange themselves. The brown liquid was frozen in place, as a solid with an irregular liquid structure. It looked the same – transparent and smooth – but now the molecules were locked into an irregular mosaic. We hit it and it shattered like glass.

This is the wonderful thing about sugar. It can exist as both a crystal and as a glass, depending on how quickly it's cooled. 'Sugar glass' used to be commonly used for props in film and theatre, since it was cheap and harmless but would shatter like the real thing.

The frustration of not being allowed to stir vanished as soon as we got to eat our glassy treat. Most of the molecules had been rearranged rather than cooked, but the change in texture was worth the effort. But I still can't see why we couldn't have stirred it. More sugary experiments are clearly needed! 🍬

Dr Helen Czerski is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, will be out in November.

NEXT ISSUE: WHAT MAKES THINGS STICKY?



COMMON SENSE

For centuries, scientists have understood that humans have five classic senses, just like many animals. However, it was only when microscopes were invented that we could really get to grips with how these senses worked. Finally, in the 20th Century, neuroethology was established. Researchers working in this field investigate the sensory perceptions of animals and humans. Over the decades, scientists have uncovered some intriguing supersenses possessed by a number of creatures.

PHOTO: GETTY



HOW DO WE KNOW...

HOW ANIMALS PERCEIVE THE WORLD

What's it like to be an animal? It seems like an impossible question, but science has taken us deep into the world of the beasts

WORDS: JULES HOWARD

P

ause for a second. Stop and think about your senses. At this very moment photons are pinging into your face where two watery spheres that sit in holes in your skull are taking them all in. These are your eyes. The lenses in your eyes (assisted by the iris) are working hard to direct the photons most effectively onto a small mass of cells at the back of your eyeballs which, upon bombardment, send electrical messages to the brain. Brilliant, isn't it?

It's taken scientists centuries to understand how our senses work. But what about other animals? Could we ever hope to understand how other species experience the world? Amazingly, the answer is yes, and the science has revealed

some senses of which we could only dream.

RODS AND RECEPTORS

For most of human history, animal perception was a total mystery. Though Buddha and Aristotle had been quick to categorise the five classic senses – touch, sight, hearing, tasting, smelling – no one could imagine how they worked. Instead, they had to resort to vague notions of 'vital forces' that flowed from sense organs into the brain.

It was with the invention of microscopes that scientists could explore bodies in a way like never before. Finally, they could look at the sense organs and see what they were made of. Eyeballs seemed like a good place to start.

Though early microscopy pioneers like Antonie van Leeuwenhoek had observed unusual looking rod- and cone-like cells at the rear of the eyeball in the 1720s, it was the German anatomist Max Schultze who first described the cellular structure of the eye in 1834, detailing the



ABOVE: Antonie van Leeuwenhoek is known as the 'father of microbiology'

BELOW: The first microscope, made by Antonie van Leeuwenhoek, had a single glass lens that was adjusted by screws

profusion of these two strange types of cell in the retina.

Schultze was a brilliant comparative anatomist. By investigating the retinas of nocturnal animals, including owls, bats, moles and hedgehogs, he noticed that cone cells in these creatures were less numerous than in our own retinas, and rod cells were more profuse. Schultze postulated that rod cells were probably responsible for detecting light in dim conditions, and that cone cells were for colour vision. He was later proved right.

This was a big leap forward in our understanding of the senses. For the first time, scientists could appreciate that there ➤



• were specific cells all over the body for detecting different types of sensory information, which were named 'receptor cells'. These cells are now known to be the most crucial part of the sensory system in humans, constantly collecting information about our surroundings.

SENSE STORY

What's more interesting, perhaps, is that the same receptor cells crop up again and again across the animal kingdom. All mammals have rod and cone cells in their eyeballs, for instance, because we all evolved them from the same animal – a small, badger-like creature that lived in the age of the dinosaurs. Natural selection hasn't re-invented sensory systems in most mammals, just tinkered with them. In this sense, our eyes and ears and noses work in exactly the same way as dogs, cats, meerkats and musk oxen.

Like other mammals, we can smell things in the air because molecules that drift into our nostrils bind onto the cell walls of specific odour receptors deep within our nose, rather like a key fits a lock. Once activated in this way, a burst of electrical current moves down an axon (the long fibres of a nerve cell) towards the brain, and we register a smell.

Likewise, we hear the world because sound waves, amplified through our mammalian ear canals, excite special finger-like projections on sensory cells deep within our heads. We taste because there are 50 to 100 taste receptor cells within each of our taste buds, and each of these cells is capable of locking onto specific molecules in our mouths. Once binded, these send electrical messages that our brain will almost instantly

associate with feelings of tastiness or 'un-tastiness'.

In fact, through microscopic analysis of the number of these receptors in a variety of creatures, we now know exactly how modest human sensory equipment is compared to our animal chums. Dogs, for instance, have 40 times the odour-sensitive receptor cells that humans have, totalling up to 300 million cells in some breeds. As well as detecting narcotics, dogs can be trained to detect rogue cancer cells, bedbug eggs and even TNT. Incredibly, this is also true of bees. In 2014, French and Croatian scientists reared a generation of 'sniffer bees' by training them to associate the smell of explosives with sugar. They hope to use these insects to seek out mines and explosives in the Balkans.

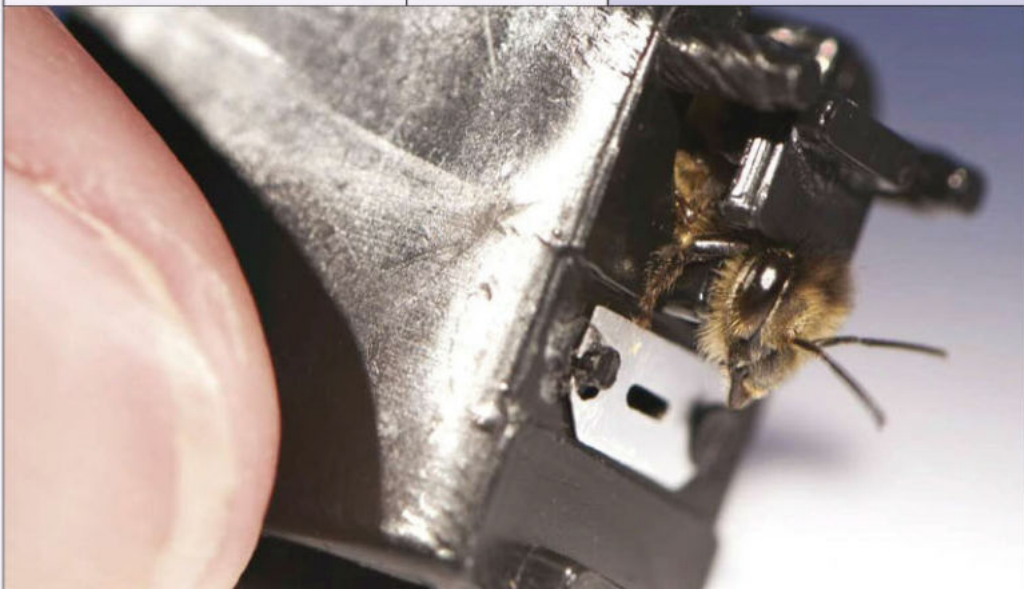
But even that is nothing compared to sharks, some species of which are able to detect as little as *one part per million* of blood in seawater. By sensing the nostril in which concentrations of blood are highest, sharks have perfected the art of homing in on prey.

Snakes also possess a host of sensory adaptations for •

BELOW: It is thought that robins may see the Earth's magnetic field, which they use to navigate (for more on robin navigation, turn to p79)



BELOW: Honey bees can be trained to detect explosives – they stick out their proboscis when the substance is present



GLOSSARY

Echolocation

The ability to navigate or hunt by emitting noises and processing the echoes from nearby objects, in the same way that ships use sonar.



Infrared

Electromagnetic radiation that lies beyond the far end of the visible light spectrum. It is emitted particularly by heated objects.



Neuroethology

Founded by Donald Griffin and Robert Galambos in the mid 20th Century, this is the area of science involved with sensory perception in animals, including humans.



Pheromone

A chemical signature produced by an animal in order to influence the behaviour of an animal of the same species. Pheromones are often about sex.



Receptor cells

These are crucial in sensory systems. When excited by an external stimulus (molecules, heat, light) they fire off an electrical signal to the brain.



Ultrasonic

Sound waves with frequencies higher than the upper limit of human hearing.

TIMELINE: ANIMAL SENSES

From quivering frogs to electrical dolphins, the story of animal senses is full of surprises

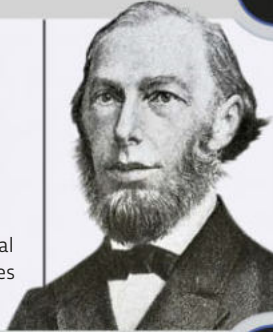
1700s



LUIGI GALVANI (1737-1798)

While dissecting a dead frog, Galvani notices its legs move when an electrical current is applied. He postulates about the role of electricity in animal bodies, an effect that becomes known as 'galvanism'.

1834



1834

Though they had long been known about, anatomist Max Schultze investigates the roles of the rod and cone cells in human eyes. The idea of specific sensory receptor cells is born.

CHARLES DARWIN (1809-1882)

Natural selection added an air of inevitability to the evolution of senses. Darwin appreciated that those with the best senses would flourish.



1941



DONALD GRIFFIN (1915-2003)

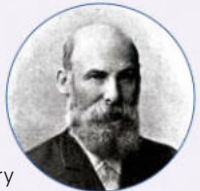
Griffin (pictured) was a co-founder of neuroethology. He went on to describe in detail a whole host of unusual methods through which bats use echolocation.

1941

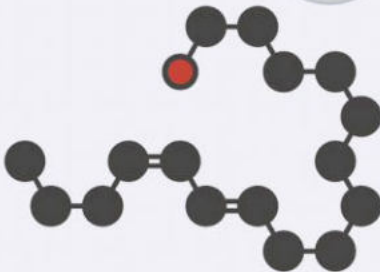
Donald Griffin and Robert Galambos finish their work on bats, uncovering the secrets of echolocation. The study of animal supersenses becomes a formal part of the zoological sciences.

JULIUS BERNSTEIN (1839-1917)

The German physiologist deduced that electric currents (including those in sensory messages) in cells are activated by ion exchange between cell membranes.



1959

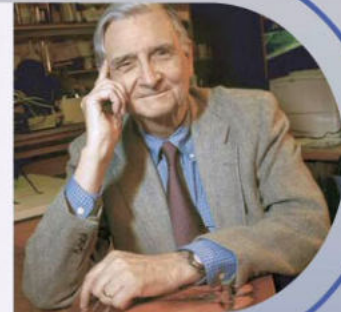


1959

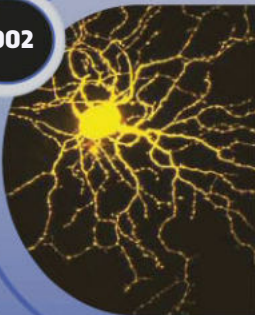
Bombykol becomes the first pheromone in the animal kingdom to be discovered and described. It is later trialled as a crop treatment to reduce moth infestations.

E O WILSON (1929-)

Over a long and distinguished career, this American sociobiologist and conservationist has uncovered the use of chemical messaging in ants to influence colony behaviour.



2002



2002

As well as rod and cone cells, a third type of photoreceptor is discovered in the eye: the retinal ganglion cells. These cells play an important role in influencing sleep rhythms.

2011

Scientists discover that the Guiana dolphin, which lives in Central and South America, can detect prey by sensing electrical fields. These sensory cells are located in a row of tiny pits on the snout.



2011

● capturing a meal. Their famous tongue deserves special mention here. This forked appendage collects odours in the air (or in water), which are then carried to an organ at the back of the mouth named the Jacobson's organ – also found in lizards, mice, elephants, dogs and many other animals. Here, odour molecules connect to receptor cells, electrical impulses fire messages, and – in the snake's case – the brain determines upon which prong of the forked tongue the 'smell' is strongest. The hungry snake moves in that direction.

Interestingly, both snakes and sharks use the same senses for hunting prey as they do for seeking sex. Males and females of many shark species are able to track one another's sexual conditions simply by sniffing out chemical calling cards (pheromones) in the environment. Indeed, advanced sensory skills are often as much about sex as they are about detecting predators and prey.

We now know that a whole host of species make use of these pheromones. One famous case involved bombykol – a pheromone produced by the female silkworm moth. After its discovery in 1959, chemical companies marketed the stuff to farmers as a way of killing the caterpillars that were eating their crops, while simultaneously reducing the use of pesticides. Bombykol was sprayed onto the farmers' fields and millions of male moths met their end, over-stimulated by the sudden appearance of a million imaginary females. Today, pheromones might hold the key to managing populations of many pests and parasites, including mosquitoes.

Sight, sound, smell, taste and touch. To scientists of the early 20th Century, it seemed as if

everything had been wrapped up. Aristotle had been right about the five senses, they had deduced, and now they had a growing understanding of the sensory cells in humans and all other animals: the receptors.

Except there was a problem: bats. Bats possessed tiny eyes that looked barely fit for purpose. Yet they flew ably at night and even hunted moths and mosquitoes on the wing. They appeared to be using a sense other animals, including humans, didn't possess. How did they do this? Could there really be such a thing as a... *supersense*?

GOING BATTY

Incredibly, it wasn't until the 1940s that we had an answer. Though many scientists had attempted to solve the mystery, it took two plucky American experimental biologists by the names of Donald Griffin and Robert Galambos to figure out what was going on.

Between 1939 and 1941, working out of a pitch black experimental room, Griffin and Galambos uncovered the bats' secrets and made the breakthrough: animals had the potential to perceive the world in ways that humans couldn't. Bats could emit ultrasonic noises and process the returning echoes to create a three-dimensional map of the world. Griffin called this sense 'echolocation'.

Though such an ability seems obvious to us now, at the time, only 75 years ago, the idea of supersenses was highly contentious. After the discovery, Griffin wrote:

THE KEY EXPERIMENT

Scientists: Donald Griffin and Robert Galambos

Date: 1939-41

Discovery: Bats navigate using ultrasound

Griffin and Galambos's experiment to determine how bats navigate is among the finest in the history of zoology.

First, by converting sound waves to electrical signals that could be read by a machine (an early ultrasonic detector) the two scientists determined that bats emitted streams of intense sounds at frequencies beyond the range of human hearing.

Second, in the most famous part of their experiments, they undertook a host of obstacle avoidance tests, using bats with temporarily impaired senses (through the use of tiny ear plugs and mouth restraints). Bats were encouraged to fly from one end of a tunnel to the other, navigating through wires which dangled from the ceiling. Those bats with impaired hearing failed the test, as did those that were impaired in their ability to produce sound.

Finally, the two scientists managed to demonstrate that, when stimulated with ultrasonic sounds, the bats' cochleas (the snail shaped region of the inner ear) produced electrical signals just like the sensory systems of other animals.

The results were clear. Bats got their bearings using sound, building a map of the world by measuring the echoes off nearby objects, vibrations from which were transferred into electrical impulses that travelled to the brain.

Robert Galambos (pictured), together with Donald Griffin, established that bats use echolocation to navigate, rather like military sonar

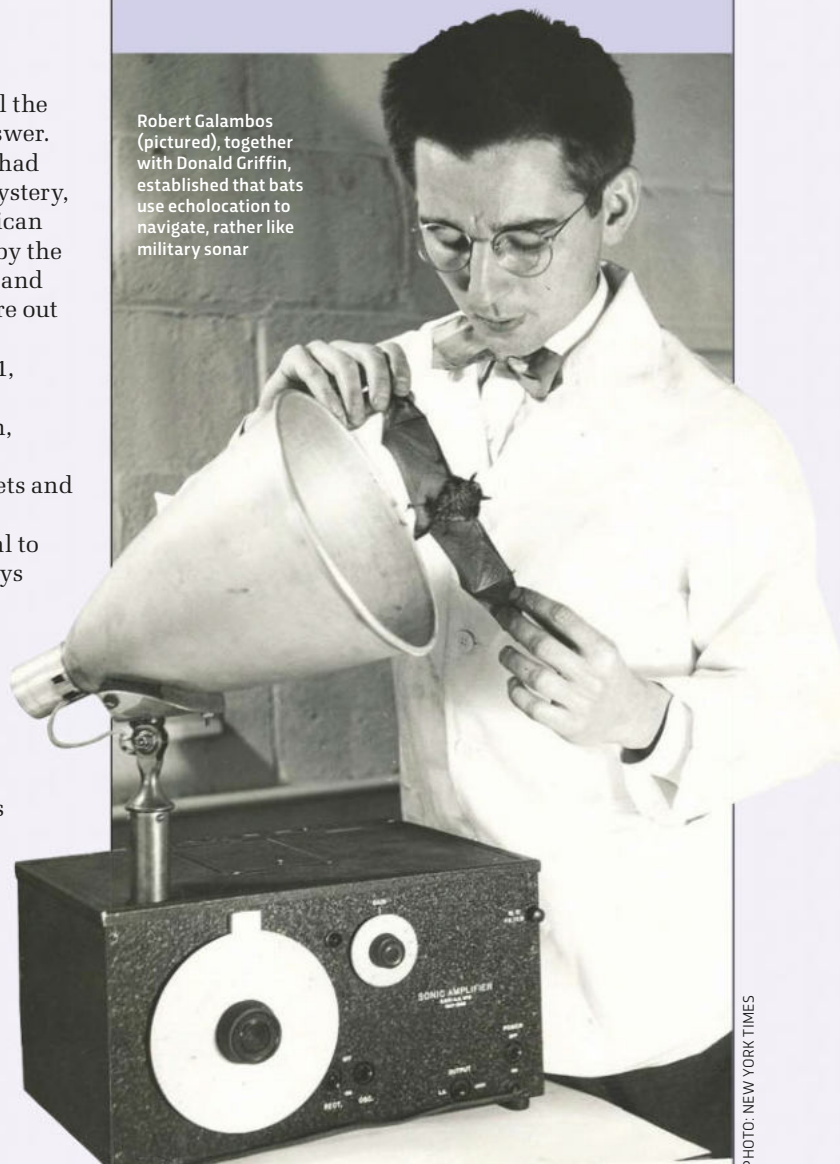


PHOTO: NEW YORK TIMES



“Radar and sonar were still highly classified developments in military technology, and the notion that bats might do anything even remotely analogous to the latest triumphs of electronic engineering struck most people as not only implausible but emotionally repugnant.”

Griffin went on to become an esteemed sensory scientist, and bats continued to be an inspiration. With his colleagues he went on to detail how bats use echolocation to hunt; how they can discriminate between prey types mid-flight; and even how some can ‘read’ ripples in the surface of water to locate invertebrates drowning in lakes and ponds.

From the 1940s onwards, Griffin, together with Galambos,

ABOVE: A snake's forked tongue allows it to detect which direction a smell is coming from, therefore helping it to track down prey

BELOW: Sharks are equipped with some powerful senses. As well as being able to detect tiny amounts of blood in water, they can also sense the electricity given off by all living things

founded the science of ‘neuroethology’ – the exploration of sensory worlds. Bats turned out to be just one of many groups of animals that

use sonar. Others are toothed whales and dolphins, some shrews, and certain birds such as cave swiftlets and oilbirds. There are even some indications that humans afflicted with blindness have a knack for it. Through the use of tongue clicks, a number of expert human echolocators have claimed to be able to listen to and process echoes in order to find their way around.

ACTIVATE SUPERSENSE!

Over the past few decades, scientists have discovered that animals use whole swathes of sensory equipment that we humans can only imagine: bees that see right into the ultraviolet spectrum of light; sharks and dolphins that hunt through the detection of electricity given off by prey; birds that migrate tens

RIGHT: Bats fire out high-pitched squeaks and listen for returning echoes to build a map of their surroundings



of thousands of miles guided by the magnetic lines of Earth; cattle that spontaneously align themselves north-south.

There are snakes of many species that can detect and home in on the infrared radiation given off by warm-blooded prey; spiders that can detect the mechanical strain on their bodies to assess force and vibration; fish that can detect pressure waves in water and use this information to modify their buoyancy. The science of neuroethology lives on today, and there are undoubtedly more supersenses out there waiting to be discovered.

Bombarded by information from our surroundings, we – the animals of Earth – effortlessly siphon off what we need to thrive and survive. We have gone about this our entire lives. And these messages are fired towards our brains in great streams of electricity, a once-mysterious power tamed by natural selection.

What took more than 500 million years of evolution to hone and craft took anatomists, experimental biologists and neuroethologists a surprising number of centuries to pick apart. And there is an irony here: bats, once viewed as creatures with sensory impairment, were the animals that helped us see most clearly how incredible sensory systems can be. **F**

Jules Howard is a science writer and author of *Sex On Earth* and *Death On Earth*. Follow him on Twitter at @juleslhoward.

DISCOVER MORE

Visit the BBC iWonder website to read a feature about what animals can see, hear and smell at bbc.in/1sSX5wi

NEXT MONTH: UNDERSTAND MUSIC



OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

JULY 2016

EDITED BY JAMES LLOYD

DISCOVER MORE

For more TV, radio and events listings, check out #BrainFood, published every Friday on our website bit.ly/BBCFocusBrainFood

Have a great night out at Jodrell Bank, under the imposing shadow of Lovell Telescope

PHOTO: ED RHODES/ALAMY

01 PARTY UNDER THE STARS

BLUEDOT FESTIVAL

JODRELL BANK, CHESHIRE,
22-24 JULY,
DISCOVERTHEBLUEDOT.COM

Jodrell Bank's iconic Lovell Telescope will play host to a different kind of stargazing this July, with the inaugural Bluedot Festival – an intergalactic weekend of music, science, arts and comedy.

The music has a distinct electronic edge, with sets from Underworld, Caribou, Air and Jean-Michel Jarre, as well as a live art installation from Brian Eno. There'll be a space-themed quiz hosted by comedian Helen Keen, and a live version of *The Infinite Monkey Cage* with Brian Cox and *BBC Focus* columnist Robin Ince.

There will also be plenty of chances to do some more traditional star spotting, with experts on hand to provide late night talks and tours of the night sky.



02

IMMERSE OURSELVES IN COLOUR

In the natural world, colour can be the difference between life and death. Every aspect of an animal's colouring has been honed over millions of years of evolution. It can act as a warning, a disguise, a distraction, or an irresistible invitation.

Opening at London's Natural History Museum this month, *Colour And Vision* explores this kaleidoscopic world. Examine more than 350 specimens, including fossils of the first organisms with eyes, a selection of today's most colourful creatures, and a collection of eyeballs from across the animal kingdom.

Visitors will also be able to explore their own relationship with colour through interactive exhibits and immersive films, while there's a gorgeous new light installation by British artist Liz West, inspired by Newton's colour spectrum and the Natural History Museum's collection of blue morpho butterflies.

COLOUR AND VISION: THROUGH THE EYES OF NATURE

NATURAL HISTORY MUSEUM, LONDON,
15 JULY – 6 NOVEMBER 2016.

DON'T MISS

FORCES OF NATURE

In his first series for BBC One, Brian Cox embarks on a grand tour of the Earth to reveal the forces that make our planet what it is. Tune in from 4 July.

03

CELEBRATE SAT-NAV

We'd be lost without GPS. In his new book, *Pinpoint*, GREG MILNER explores the science and history of this technology. He speaks to JAMES LLOYD

PINPOINT: HOW GPS IS CHANGING OUR WORLD
BY GREG MILNER
IS OUT 7 JULY
(£14.99, GRANTA).

What exactly is GPS?

The Global Positioning System is a constellation of 31 satellites – 24 of which are active at any one time – that transmit a radio signal. If a GPS receiver can pick up at least four of these signals simultaneously, it can extrapolate its position in three dimensions (latitude, longitude and altitude).

The system itself is completely owned by the US Department of Defense – it was actually begun in the early 1970s as a potential way of dropping bombs with greater precision. A lot of the early champions of the technology were veterans of the air campaigns in Vietnam, who were driven by a desire to come up with a more humane method of air warfare. But from the very beginning, GPS was also used by civilians, and people began to realise that there were all kinds of applications for this free, incredibly accurate signal.

Where's the most unusual place that GPS is used?

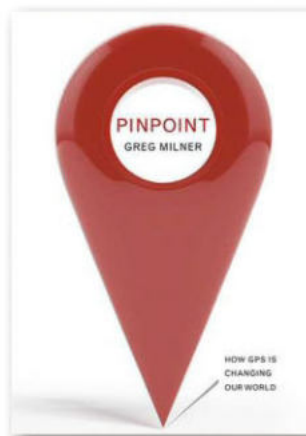
The same thing that's guiding cars is used by scientists to help foresee earthquakes, guide spacecraft to Mars, measure the moisture in drought-affected regions, and even calculate the speed of subatomic particles. Perhaps the greatest achievement of GPS, though, is its use in precision agriculture, which is growing at an astounding rate in Asia and the Pacific. If you can know exactly where a seed is planted, and where exactly to place the water, fertiliser and harvesting equipment, you save an enormous amount of money. Farmers are some of the most sophisticated users of GPS today.

Is there a downside to GPS?

It can be overused – I talk about 'death by GPS', where people blindly follow sat-nav instructions and end up driving their car into a lake. We've adapted to the technology so quickly that we're only just understanding the effect it might be having on our cognitive maps. Scientists have shown that an overreliance on GPS can lead to a detachment from your surroundings and a lack of situational awareness. There's even evidence that it might be changing our brain structures.

What would happen if GPS failed?

GPS is used in cellular and landline phone networks; it's used to regulate the electrical grid; it's used for timestamping financial transactions. Ships are dependent on it for navigation. All kinds of systems would fail. There'd be chaos, massive inconvenience, and billions of dollars of damage. The US Air Force likes to call GPS the world's only global utility, and now I'm convinced that's true. The modern world really does rest on the foundation of GPS.



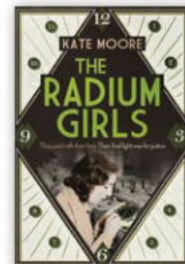
ALSO OUT THIS MONTH

**HOME LAB**
BY ROBERT WINSTON

Out 1 July (£12.99, Dorling Kindersley).

Inspire the scientists of the future with this collection of 28 hands-on projects for kids.

Features erupting volcanoes, soap-powered boats and homemade bath bombs, as well as a guide to the science behind every experiment.

**THE RADIUM GIRLS**
BY KATE MOORE

Out now (£16.99, Simon & Schuster).

The tragic true story of the US women who painted dials onto watches

and instruments during WWI. Poisoned by the luminous radium paint they used, this book tells how they fought for justice amid the horror of a certain death.

**MAKE WAY FOR THE SUPERHUMANS**
BY MICHAEL BESS

Out 7 July (£14.99, Icon Books).

Robotic implants, brain-to-brain interfaces, 3D-printed

organs... there seems to be a new breakthrough in bioenhancement every week. Michael Bess looks at the current state of the technology, and asks where it's heading.

04 MASTER THE BBC MICRO:BIT

It's time to get those creative juices flowing. Previously given away to one million Year 7 schoolchildren across the UK, the BBC micro:bit is now available to anyone who wants to try their hand at a spot of coding. The credit card-sized computer – which features 25 LEDs, two programmable buttons, an accelerometer, a compass, and multiple input/output rings – can be purchased online for £12.99. Here are five of our favourite project ideas:



1 MICRO GUARDIAN

Keep grubby hands away from your jar of treats by turning it into an alarmed stronghold. Strips of copper tape inside the jar and lid create a circuit that's broken when the jar is opened, with the micro:bit programmed to sound a buzzer.

MAKE.TECHWILLSAVEUS.COM/PROJECTS/MICROGUARDIAN



3 ELECTRO FOOTBALL

Construct a miniature goal out of cardboard and kitchen foil, then wire it up to a micro:bit and a buzzer. With a nifty bit of coding, the micro:bit will serve as an electronic scorecard, counting and sounding each time the ball hits the back of the net. Boof!

MAKE.TECHWILLSAVEUS.COM/PROJECTS/MICROFOOTBALL



2 STEP COUNTER

Turning the micro:bit into a pedometer is simple. The device's built-in accelerometer can detect when it's been shaken, with the number of steps displayed on the LED screen. The tricky part is getting up those stairs...

MICROBIT.CO.UK/IET/STEPOMETER



4 ROCKET PENCIL CASE

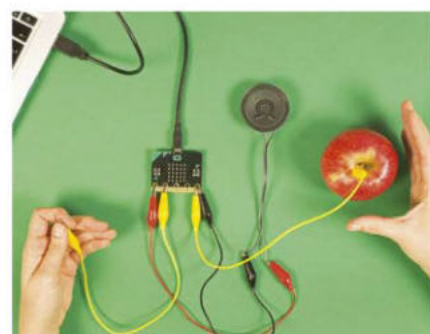
If Tim Peake took pencils into space, this is what he'd use. The felt pencil case features an extra row of LEDs – connected to the micro:bit with conductive thread – and is programmed to display a countdown. Blast off!

KITRONIK.CO.UK/BLOG/BBC-MICROBIT-COUNTDOWN-PENCIL-CASE/

5 TOUCH ARPEGGIATOR

A piece of fruit might not sound like the most obvious musical instrument, but hook one up to the micro:bit for your very own touch-activated tone generator. The buzzer will start playing musical scales when you hold the fruit and complete the circuit.

MAKE.TECHWILLSAVEUS.COM/PROJECTS/TOUCH-ARPEGGIATOR



TOMOKO NAKANISHI SHARES HER FAVOURITE SPOTS IN TOKYO



1 TOTO MUSEUM

Founded by Japanese toilet manufacturer TOTO, this museum celebrates all things lavatorial.

2-1-1 Nakashima, Kokurakita
toto.co.jp/museum/en/

2 NEZU MUSEUM

Houses the pre-modern Japanese and East Asian art collection of politician and businessman Nezu Kaichirō (1860-1940).

6-5-1 Minami-Aoyama, Minato
www.nezu-muse.or.jp/en/

3 SHIBAMATA TAISHAKUTEN

Buddhist temple in Katsushika, northeast Tokyo. 7-10-3 Shibamata, Katsushika

4 TSUKUDAJIMA

Old part of the city that survived the Great Kantō Earthquake and WWII.

5 UMENOHANA

A restaurant in the Ueno area that specialises in tofu dishes.

1-20-11 Ueno, Taito
umenohana.co.jp

6 OOEDO-ONSEN MONOGATARI

This spa offers hot spring baths, amusement arcades and Japanese eateries.

2-6-3 Aomi, Koto
oedoonsen.jp

Tomoko Nakanishi is a professor at the University of Tokyo and an expert on the effects of radioactive fallout on plants and agriculture.

Tokyo is a lovely place to live, because it has a grand and chaotic mix of the old and new. But there is order among the chaos. It's actually a quiet city, as few Japanese people talk loudly when out and about – they don't speak when taking the lift or chat loudly on a train. Even children whisper. People from Tokyo are refined ('iki') and generous, straightforward and cheerful ('kippu no yosa').

It's also a very clean city. For example, our toilet system often surprises visitors, as everything is automatic – even the lid opening. Our younger generation take these things for granted, so they are often surprised when they go abroad. **THE TOTO 'TOILET' MUSEUM** 1 gives an insight into how our sanitary system and waste management programmes developed.

One of my favourite museums is the **NEZU MUSEUM** 2, which is rather small but the garden and building are beautiful, and exhibitions are always excellent. The Tokyo National Museum is also great, as it explains Japanese history and arts, while the National Museum of Nature and

Science portrays the evolution of science and technology in Japan.

Probably my favourite temple in Tokyo is the old Buddhist temple **SHIBAMATA TAISHAKUTEN** 3. It's famous for its wooden statue of the deity Taishakuten that was lost for many years before being rediscovered in 1779 covered in soot in the temple's attic. The grounds have a very Japanese feel, and the area is known for its dumplings.

The area **TSUKUDAJIMA** 4 is renowned for its old buildings and close community, and also for the many houses serving traditional pickled foods. But one of my favourite places to eat is the **UMENOHANA TOFU RESTAURANT** 5 in the Ueno area. All the dishes are delicious and the price is reasonable, especially at lunchtime.

And I love to relax in one of Tokyo's many hot spas! At the **OOEDO-ONSEN MONOGATARI** 6 hot spring theme park everyone dresses in yukata – a type of kimono usually made of cotton and often worn in the summer. Spa culture is very much part of Japanese life. In Tokyo, there are even hot spas for dogs! 6



BBC

COUNTRYFILE

Blenheim Palace
4 - 7 Aug 2016

LIVE

Sponsored by
 **QUILTER
CHEVIOT**
INVESTMENT MANAGEMENT

In association with
 **National Trust**

THE
BIG
NEW EVENT
IN 2016
ADVANCE TICKETS
£24*



Four extraordinary days showcasing **THE BEST OF THE BRITISH COUNTRYSIDE**

SO MUCH TO SEE AND ENJOY

JOIN THE COUNTRYFILE PRESENTERS • DISCOVER ADAM'S FARM • THE LATEST FARM MACHINERY DISPLAYS
THE GREAT BRITISH ICE CREAM PARLOUR • THE NATIONAL TRUST THEATRE • OFF ROAD EXPERIENCE
SHOPPING AT HUNDREDS OF FOOD AND CRAFT STALLS • CRAFTS IN ACTION • A VINTAGE FUN FAIR
WILD ANIMALS & RARE BREEDS • OUTDOOR FUN FOR KIDS • EQUINE VILLAGE
THE BEST OF BRITISH FOOD & DRINK • DOG DISPLAYS
AND MUCH MORE...

BOOK IN ADVANCE AND SAVE AT **COUNTRYFILELIVE.COM** | **0844 249 1000**

Calls to this number will cost 7p per minute, plus your telephone company's access charge. Please consult your telephone provider for further details.
*Ticket price plus booking and transaction fees.

eventim

Official Magazine

 **COUNTRYFILE**
MAGAZINE

Theatre presented by

 **National Trust**

4x4 feature sponsor



The Big Barn sponsor



#countryfilelive

Countryfile Live is produced by SME London Ltd under license from BBC Worldwide. BBC logo © 1996. Countryfile Live logo © BBC 2015

 **BBC**

BBC FOCUS

EDITORIAL

Acting editor Daniel Bennett
Production editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Online editor Alexander McNamara
Editorial assistant James Lloyd
Science consultant Robert Matthews
Contributing editors Emma Bayley, Russell Deeks

ART

Art editor Joe Eden
Designer Steve Boswell
Picture editor James Cutmore
Group art editor Susanne Frank

CONTRIBUTORS

Acute Graphics, Rob Banino, Peter Bentley, JV Chamary, Stuart Clark, Jamie Coe, Helen Czerski, Eiko Djala, Adam Gale, Alastair Gunn, Jules Howard, Robin Ince, Christian Jarrett, Tonwen Jones, Pierre Daniel Kleinhouse, Raja Lockett, Mark Lorch, Orlagh Murphy, Henry Nicholls, Catherine E Offord, James Olstein, Jheni Osman, Elizabeth Pearson, Chris Philpot, Helen Pilcher, Andy Potts, Secret Studio, Colin Stuart, Luis Villazon, James Witts, Giles Yeo

ADVERTISING & MARKETING

Group advertising manager Tom Drew
Advertising manager Neil Lloyd
Senior brand sales executive Jonathan Horwood
Brand sales executive Anastasia Jones
Senior classified executive Jenna-Vie Harvey
Newstrade manager Rob Brock
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane

MOBILE

Product and development director Richard Fennell
Head of apps and digital edition marketing Mark Summerton

INSERTS

Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION

Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION

Production director Sarah Powell
Production coordinator Emily Mounter
Ad services manager Paul Thornton
Ad coordinator Jade O'Halloran
Ad designer Rachel Shircore

PUBLISHING

Publisher Jemima Ransome
Publishing director Andy Healy
Managing director Andy Marshall
Chief executive officer Tom Bureau
Deputy chairman Peter Phippen
Chairman Stephen Alexander

BBC WORLDWIDE, UK PUBLISHING

Director of editorial governance Nicholas Brett
Director of consumer products and publishing Andrew Moultrie

Head of UK publishing Chris Kerwin
Publisher Mandy Thwaites
Publishing coordinator Eva Abramik
Contact UK.Publishing@bbc.com
www.bbcworldwide.com/uk--anz/ukpublishing.aspx

EDITORIAL COMPLAINTS

editorialcomplaints@immediate.co.uk

ANNUAL SUBSCRIPTION RATES (INC P&P):

UK/BFPO £55.25; Europe & Eire Airmail £58.50;
Rest of World Airmail £63.



Audit Bureau of Circulations
63,214 (combined; Jan-Dec 2015)

**IMMEDIATE
MEDIA^{Co}**

BBC Focus magazine is published by Immediate Media Company London Limited under licence from BBC Worldwide who help fund new BBC programmes.

© Immediate Media Co Bristol Ltd 2016. All rights reserved. Printed by William Gibbons Ltd.

Immediate Media Co Bristol Ltd accepts no responsibility in respect of products or services obtained through advertisements carried in this magazine.

NEXT MONTH

AUGUST
ISSUE
ON SALE
21 JULY

GEOBIOLOGY

Life after the dinosaurs

For the first time ever, scientists have drilled into the Chicxulub crater – the landing site of the meteorite that killed off the dinosaurs. What they find could overturn our understanding of how life recovered after the impact.

PSYCHOLOGY

GOOD TO BE BAD?

Is it better to be altruistic or selfish? Kind or mean? Honest or a cheat? We ask two experts to weigh up the relative benefits of being good and bad.



PHOTOS: SCIENCE PHOTO LIBRARY, GETTY, ISTOCK

HEALTH

DRUGS IN THE DEEP

We're desperately in need of new antibiotics – could our oceans hold the key? We meet the scientists who are searching for substances in the world's waters.



PUZZLES

THINKING CAPS ON!

Our August issue will see the return of our puzzles page, with a cryptic crossword plus mind-bending logic puzzles from stand-up mathematician Matt Parker.



WRITERS BUREAU CREATIVE WRITING COURSE

Why Not Be A Writer?

What our students say:



"I won the 2015 Flirty Fiction Prima Magazine and Mills and Boon competition. The prize was £500, a three page feature in the magazine and the chance to work with Mills and Boon on my book. Also I have three stories in three anthologies with other authors – we've raised almost £2,000 for cancer charities"

Rachel Dove, West Yorkshire



"My total earnings so far are £2,500."

Victor Wright, West Midlands



"I have been publishing my own niche website for circus critique. This work has led to recognition in my field, with work offers ranging from writing book reviews for scholarly journals to running master classes for young people. I have had two paid writing residencies at festivals this year and have been employed to write tweets. Payments total £2575, plus expenses for travel, tickets to events and payments in kind in the form of review copy books."

Katherine Kavanagh, West Midlands



"As a result of my cricket articles, I have been elected into The Cricket Writers Club – an organisation that counts experienced journalists among its members. One of the perks of this membership is a press card that gives me entry into all of England's cricket stadium press boxes."

Martin Read, West Sussex



"I've been published in The Guardian and Good Life earning £400. And now I've got my first book published by Bloomsbury called MOB Rule: Lessons Learned by a Mother of Boys. The Writers Bureau course provided me with structure, stopped my procrastination but most importantly it provided the impetus to try something different."

Hannah Evans, Winchester



"When I first saw my words in print it was life changing. Someone else had read my work, believed in it, paid for it, and put it out there for others to see. As more articles made it to press, my confidence grew and I found I wanted to inject some of myself into my writing. At the time of writing this I have received £1,197 for my work."

Kris Roberts, Somerset

Being a writer can offer you a second income, extra spending money or it can even be a full-time career. It's your choice. But whatever your writing ambitions, we have a course that will help you to achieve them.

That's because our first-class home-study creative writing course contains all you need to know to become a successful, published writer. You learn how to write articles, short stories, novels, TV, radio, drama and more. You are shown how to develop your writing style, present your manuscripts, contact editors, find markets and HOW TO SELL YOUR WORK.

What's more, you do not need any previous writing experience to succeed on the course as it's suitable for the absolute beginner.

Throughout the course you will be tutored by a professional writer, who will offer constructive feedback on your twenty marked assignments. In addition, you can count on the support of our dedicated Student Services team who will do all they can to ensure that you get the most out of your studies.

When you enrol, your full course is sent to you on a **fifteen day trial**. Your studies are then flexible to your requirements. Moreover, we offer you a **full refund guarantee**. If you do not earn back the equivalent of your fees by the time you finish your course we will refund them in full.

So, if you would like to learn how to earn from writing, try our risk-free course. For a free prospectus visit our website or call our freephone number today!

www.writersbureau.com

FREE CALL
24 HRS

0800 856 2008

Quote:
JL23616

YES! Please send me free details on how to become a successful, freelance writer.

Name: _____

Address: _____

Postcode: _____

Email: _____

Freepost RSSK-JZAC-JCJG

The Writers Bureau

Dept JL23616

Manchester, M3 1LE



www.facebook.com/thewritersbureau
www.twitter.com/writersbureau

email: 16W1@writersbureau.com

Please include your name and address



Members of BILD and ABCC

Enrol online to access your course modules TODAY at: www.writersbureau.com

Coding, Robotics, Game Design ...

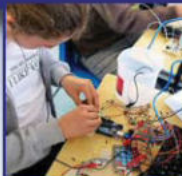
Tech Camp Exclusive Courses for 2016



Build & Fly Your Own Quadcopter



Learn Coding and Make a Robot Arm



Build Gadgets in Inventor School



Build & Programme a Drawing Robot



Build Rockets & an Electronic Launcher



Design Your Own Games



Build a WiFi Laser Tag System

Tech Camp is the UK's original coding and engineering camp and remains the only one specialising in teaching programming through advanced take-home projects. It's perfect for creative youngsters who like making things (or taking them apart!) or to show those who are forever playing games how to start designing their own. We have tutors from the likes of Cambridge & Imperial, maximum groups of eight, and exclusive courses not available anywhere else with dedicated teen-only options.

Come as a day camper or join hundreds of other young people from around the UK at our flagship residential camps where you have your own en-suite room and spend evenings playing laser tag, disassembling electronics and much more.



techcamp
.org.uk

Inspiring Tomorrow's Inventors

Tech Camp London (Non-Residential) & Tech Camp UK (Residential)
www.techcamp.org.uk 0118 380 5678

2GRAPHIC
Photo-Restoration.co.uk
EST 2003



We can:
Revive faded photos
Repair creases & tears
Recreate missing parts
Enlarge small photos
Colour B&W photographs
Piece together torn photos
and more...

*No money upfront
Not happy, don't pay*

tel: 01274 900968
info@photo-restoration.co.uk

www.photo-restoration.co.uk

WB



FREE UK
DELIVERY


Designer brand watches at cheap
discount prices

UP TO **50% OFF**

www.wristybusiness.co.uk


365 Astronomy

Discovery for every day!



TELESCOPES, BINOCULARS, SPOTTING SCOPES, MICROSCOPES & A WIDE RANGE OF CCD & DSLR CAMERAS & ASTRO PHOTO ACCESSORIES FOR SCIENTISTS & ENTHUSIASTS

From world leading brands: Baader, Celestron, Fornax, Moravian Instruments, Skywatcher, Primaluce Lab, ZWO & many more




Call 020 33 845 187 between 9am - 9pm 7 days a week.
www.365astronomy.com

MIGHTYFINE

— THE SPIRIT OF TRAVEL —

Magic by Day, Magic by Night




Holiday with us to see the Northern Lights and we'll ensure that every moment of your holiday is as magical as the mystical Aurora Borealis!

We'll make your daytimes just as exciting as your evenings with thrilling snowmobile and husky safaris and delightful introductions to local culture. We'll put you in the hands of expert local guides, take you to the most fascinating locations.

If you love the Northern Lights, you'll love The Mighty Fine Company. Call us today and let the magic begin!

www.mightyfinecompany.com
sales@mightyfinecompany.com

Tel: 0333 121 0370



AMAZING FIZZPOP[®]

SCIENCE PARTIES!

For ages 5yrs to 12yrs

Experiment!

Discover!

Inspire!





Slime Party



Rainbow Bubble Party



Hair Raising Party



Tasty Fizz Pop Sweet Party

PARTIES

CLUBS

SHOWS

Contact us about our 'Free shows for Primary Schools'

WORKSHOPS

EVENTS

www.fizzpopscience.co.uk

TEL: 0330 660 0445





Digital Microscopes



Micro Fi

Stream. Capture. Share.

Micro Fi is a Wi-Fi enabled handheld digital microscope that enables you to view the microscopic world right on your smartphone or tablet!



Celestron Microscopes are available from



01 502 725205
and specialist dealers nationwide

TetraView™

The professional-level Celestron TetraView LCD is a touchscreen digital microscope with advanced features at a reasonable price. TetraView features four fully achromatic lens objectives, a fully mechanical stage, a 4.3" TFT full colour touch screen, 5 MP CMOS sensor, and a 2 GB SD card for storing your photos and videos. Taking high-resolution images and video of specimen slides has never been easier.

Handheld Pro 5MP Digital Microscope

Easy to use, low-power microscope with a large 5.0 MP sensor and stand.



Celestron is distributed in the UK and Ireland by David Hinds Ltd. Dealer enquiries welcomed.
David Hinds Ltd. Unit R, Cherrycourt Way, Leighton Buzzard, Bedfordshire LU7 4UH

Celestron® and TetraView™ are registered trademarks or trademarks of Celestron Acquisition, LLC in the United States and in dozens of other countries around the world. All rights reserved. Samsung is a registered trademark of Samsung Electronics Co., Ltd. AppStore is a registered trademark of Apple Inc. Google Play is a registered trademark of Google Inc.

See more with Celestron
www.celestron.uk.com

LOOKING TO BE PUBLISHED?

SUBMISSIONS AND SAMPLES WELCOMED. ALL WORK CONSIDERED, NO AGENT REQUIRED.

AUSTIN MACAULEY
PUBLISHERS LTD.

CGC-33-01, 25 Canada Square
Canary Wharf, London, E14 5LQ
Tel: 0207 038 8212
www.austinmacauley.com
mail@austinmacauley.com

Distance Learning Courses



Masters Courses

MSc Astrophysics
MSc Observational Astrophysics

Starts
Sept
Sept

Some of our short Courses

An Introduction to Astronomy
Science with the Liverpool Telescope
The Science of the Night Sky
High Energy Astrophysics

Starts
Sept
Oct
Nov
Jun

astronomy.ac.uk astro-distance@ljmu.ac.uk / 0151 231 2900

Est. 1970
IAN EDWARDS
OF HARROGATE Est. 1970

Tel: **01423 500442**

for sales/enquiries or FREE brochure call - 01423 500442
www.iansbespokefurniture.co.uk



Handmade Bespoke Furniture
for CD's • LP's • DVD's & Books

The Old Chapel, 282 Skipton Road,
Harrogate, Yorkshire HG1 3HE

“In this country, people seem to think that maths is irrelevant and uninteresting”

Mathematician and TV presenter **Hannah Fry** talks to **Helen Pilcher** about her love of maths, Formula 1 and her dog Molly

I use maths to look at patterns in human behaviour. People leave behind traces of themselves in the data they create. When you start to look, say, at where people spend their money or where burglaries happen, you find there are patterns that can be described mathematically. You can then look at what causes these patterns and think about ways of redesigning the environment for the better.

I wanted to be a hairdresser when I was at school. But my mum steered me towards doing A-levels. My dad was a pro motorbike racer, so I also quite fancied Formula 1!

I wasn't particularly brilliant at maths when I was young, but one summer holiday when I was 11 my mum bought me a maths textbook and insisted I work my way through it. Then, next term, I found that I was ahead of everyone. I realised that the more investment I put in, the more enjoyable it became.

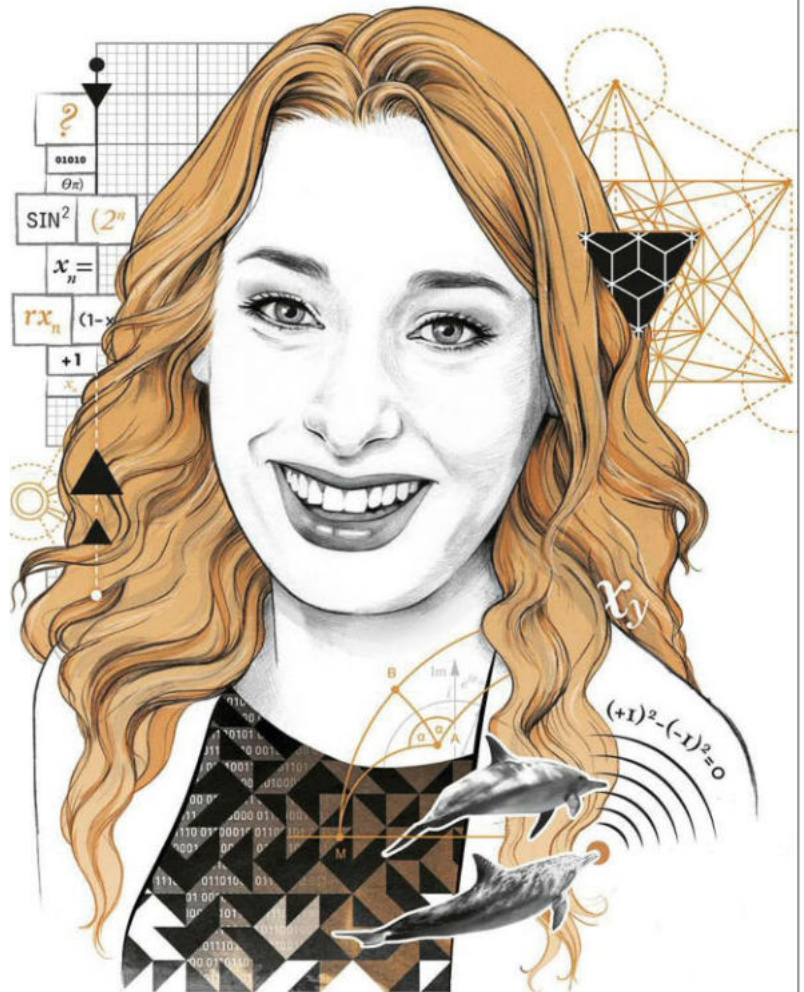
That's the thing about maths. You can't expect to enjoy it without putting in the time and the effort. I often hear people say that they can't 'do maths', or that you have to be naturally gifted at it. But that's not the case.

In this country, people seem to think that maths is irrelevant and uninteresting. That's a real shame, because this perception couldn't be further from the truth. Yes, it might be difficult but if ever there were a subject that's a natural playground, it's maths. It's a subject that is ripe for joyful discovery.

Animals can do maths. Lots of animals can distinguish between quantities that are bigger and smaller, but dolphins are unbelievable. They intuitively know how to add, subtract, multiply and understand ratios, and use these skills to help catch fish.

I split my time between a real academic job and mucking around doing TV and radio. I've been ridiculously lucky. I travel a lot. One day, I get to fly in a helicopter over the desert in Dubai, the next I'm talking to a master brewer about making the perfect cup of tea. And the next I'm in my office surrounded by equations.


I like going for walks with my dog, Molly. She looks like a



teddy and is pure goodness. She's quite naughty, but only because I don't train her properly – I find it hard to tell her off. The other day, she buried some frozen mango in the house. That'll biodegrade nicely.

I'd like to pause the world and do 10 different degrees.

I'd like to be a better computer programmer. If you're good, it's like plugging your brain directly into a computer. It's very creative.

I am micro-ambitious. It's not about five-year plans: the best thing to do is grab whatever opportunities are put in front of you and do the best you can with them. I'm just enjoying the ride while it lasts. 

Hannah Fry is a lecturer in the mathematics of cities at University College London.

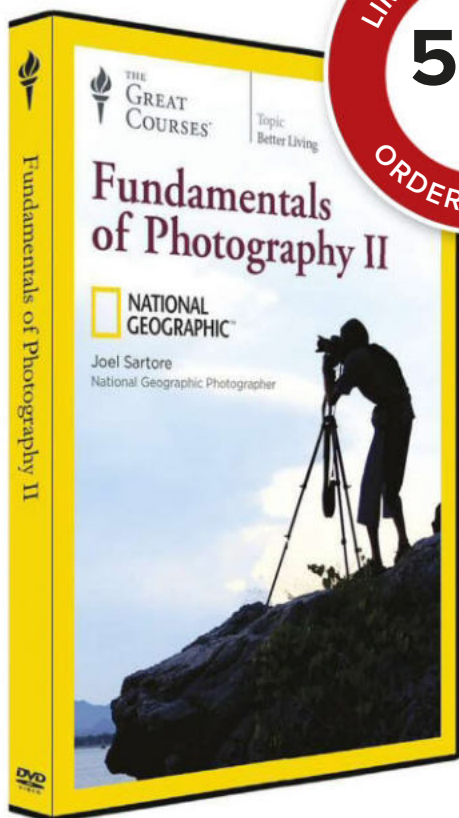
DISCOVER MORE



To listen to episodes of *The Life Scientific* with top scientists, visit

bit.ly/life_scientific

NEXT ISSUE: JOHN ROBERTS



Elevate Your Photographs from Good to Amazing

You may already take great photographs, but you can make your photographs amazing. **Fundamentals of Photography II** is an immersive photography workshop that goes beyond the topics covered in our popular course **Fundamentals of Photography**. This course looks at photography as the art of problem solving, especially as you're out in the world taking photographs.

Under the expert guidance of National Geographic photographer Joel Sartore, you will cover topics as diverse as underwater and aerial shots, portraits, reflections and shadows, taking studio lighting outdoors, night photography, black-and-white photography, and smartphone photography. These lessons take you into the field to assess and anticipate shooting situations and develop your critical eye to get intriguing, moving, memorable, and truly amazing results.

Offer expires 24/07/16

THEGREATCOURSES.CO.UK/8FS

0800 298 9796

Fundamentals of Photography II

Taught by Joel Sartore
NATIONAL GEOGRAPHIC PHOTOGRAPHER

LECTURE TITLES

1. Find the Picture
2. Understanding Light
3. Working with Light in a Landscape
4. Taking Photos under and around Water
5. Photographing Reflections and Reflectivity
6. Photographing Shadows and Backlighting
7. Big Results from Little Lights
8. Taking Studio Lights Outdoors
9. Human Portrait Photography
10. Animal Photography
11. Night Photography
12. Art Photography: Perspective and Illusions
13. Art Photography: Having Fun
14. Art Photography: Still Life
15. Black-and-White Photography
16. Elevating Your Perspective: Photos from Above
17. Smartphone Photography
18. The Decisive Moment in Photography
19. Live Event Photography: Farmers' Market
20. Live Event Photography: T-Ball
21. Live Event Photography: House Party
22. Live Event Photography: A Day at the Ranch
23. Live Event Photography: Family Fishing Night
24. Editing, Culling, and Critiquing Your Photos

Fundamentals of Photography II

Course no. 7931 | 24 lectures (30 minutes/lecture)

SAVE £30

DVD ~~£54.99~~ NOW £24.99

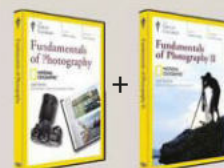
+£2.99 Postage and Packing
Priority Code: 129293

SPECIAL SET OFFER!

Learn the Art and Craft of Photography with This Two Volume Set:

Fundamentals of Photography and Fundamentals of Photography II

Purchase Set No. 7932



SAVE £66 on these two courses!

DVD ~~£102.98~~ NOW £36.98

+£2.99 Postage and Packing
Priority Code: 129293



**SHOULDERS WERE
MADE FOR GLORY**

NOT DANDRUFF

